

SESSION X

FILTERS, FILTRATION, AND FILTER TESTING

Wednesday, August 30, 1972

Co-Chairmen: H. Gilbert & M. D. Thaxter

DEEP-BED FILTER PERFORMANCE TESTS

G. A. Schurr, D. B. Zippler,
D. C. Guyton

ADEQUACY OF VENTILATION EXHAUST FILTERING SYSTEM FOR NEW PLUTONIUM
FACILITIES

N. Hetland, J. L. Russell, Jr.

EFFECTS OF HIGH LEVEL GAMMA RADIATION EXPOSURE OF HEPA FILTERS

C. L. Cheever, C. H. Youngquist,
P. R. Hirsch, J. C. Hoh,
D. S. Janetka, H. R. Fish

IN-PLACE EFFICIENCY TESTS OF A LARGE-SCALE VENTILATION EXHAUST FILTER

B. J. Grady, Jr., K. H. Henry

EFFECTS OF RADIATION ON REACTOR CONFINEMENT SYSTEM MATERIALS

L. R. Jones

PERFORMANCE OF ABSOLUTE FILTERS AT TEMPERATURES FROM AMBIENT TO
1000°F

M. W. First

CONFINEMENT OF AIRBORNE ACTIVITY FROM MELTED ANTIMONY SLUGS

J. W. Little, Jr., J. W. Joseph Jr.

HIGH CAPACITY DOP AEROSOL GENERATOR: PROGRESS REPORT

A. G. Rolie, F. E. Adley

REPORT OF THE GOVERNMENT-INDUSTRY COMMITTEE ON FILTERS, MEDIA AND
TESTING

W. L. Anderson

CHAIRMAN'S OPENING REMARKS:

Gilbert: This afternoon's topic generates quite an amount of interest. It seems to be a topic about which everybody knows a little and no one knows enough. For a number of years, the atomic energy program has had rather large filter systems backing up the chemical separations plants. More recently, there has been renewed interest in this area.

DEEP-BED FILTER PERFORMANCE TESTS*

G. A. Schurr**, D. B. Zippler, and D. C. Guyton

Savannah River Plant, E. I. du Pont de Nemours & Co.
Aiken, South Carolina 29801

Abstract

Direct comparative tests of the filtration efficiency and particle holding capacity of sand and "Fiberglas" filters have been performed. Filters tested were modeled after designs currently in use at the Savannah River Plant and Hanford Works. The test program included: (1) efficiency determinations of sand and "Fiberglas" filters using DOP aerosol testing techniques, (2) comparative evaluation of the effectiveness of specific sand deposits, (3) the effect on efficiency and ΔP as a function of moisture in the sands under test, and (4) simulated high density smoke loading of both the sand and "Fiberglas" units. The tests have provided engineering data on filter performances and specific sand efficiencies.

Introduction

Since startup sixteen years ago, the release of stack particulate activity from two chemical processing areas of the Savannah River Plant has been essentially prevented by two deep-bed sand filters. Each filter is 100 feet wide and 240 feet long, and contains sand and gravel beds seven feet deep. Air from the process facilities enters through a bottom distribution system and flows up through the bed and out a top plenum. The useable life of the filters is unknown. Recent mechanical failures that permitted loss of some of the bed supports may make it necessary to replace the filters sooner than originally expected. Filter efficiency has been determined only by measurements of the quantity of radioactive particulates in the air stream before and after it passes the filter. The gradual increase in pressure differential (ΔP) across the bed over the years and the more recent accelerated pressure differential increases across one filter has prompted the need for consideration of a new filter.

Sand and glass fiber filters have been employed at other AEC contract sites for high efficiency filtration. Juvinall, Kessie, and Steindler⁽¹⁾ summarized the historical application of the deep-bed sand filter in industrial and AEC use. A specific deep-bed sand filter designed for plutonium fume removal was discussed by McFee and Sedlet⁽²⁾. Blasewitz and Judson⁽³⁾ discussed the test and theoretical considerations leading to the deep-bed glass fiber filter design used at Hanford Works. This work was extended⁽⁴⁾ to include a comparison of both glass fiber and sand bed constructions in terms of efficiency and service longevity.

* Information in this document was developed during the course of work under Contract AT(07-2)-1 with the U. S. Atomic Energy Commission.

** Engineering Services Division of E. I. du Pont de Nemours and Co., Wilmington, Delaware.

Prior to the design of a replacement filter, a comparison of filter media ("Fiberglas," used satisfactorily at the Hanford Works, and sand, which performed satisfactorily at the Savannah River Plant) was made to test and compare the filtration efficiency, the pressure differential, and the particle-holding capacity of the two media. The data developed provide useful guidance for expected performance standards for either media, and design limitations and the advantages and disadvantages of both media were identified.

Discussion

Filter Efficiency Test Program

The efficiency of a filter system is a measure of its ability to collect particulates from an air stream. A high efficiency air filtration system is defined here as one which has a particle collection efficiency approaching 100% for 0.3 micron particles. A sand or "Fiberglas" deep-bed filter should be designed to provide similar high efficiency filtration if possible. The use of dioctylphthalate (DOP) to produce submicron particles for determining filtration efficiency is a standard procedure.

A TDA-4A DOP aerosol generator used for inplace HEPA filter testing provided the aerosol for the tests. A forward light scattering particulate detection instrument manufactured by Air-Techniques, Inc., Baltimore, Maryland, was used to measure the relative DOP aerosol concentration upstream and downstream of the test filter units.

Sand Filter Testing

The sand filter test program was designed to obtain answers to the following questions:

1. What is the efficiency of the Savannah River Plant sand filter design for submicron particles?
2. What effect does compaction of the bed have on filter performance?
3. What variation in aggregate specifications can be made to maintain or improve efficiency without an unreasonable increase in operating pressure?

Construction of Model Unit. A two-foot-square plywood box, 8 feet high, with one transparent side was constructed to hold the deep-bed filter media under test (figure 1, following tables). Fittings for 0.25 in. copper tubing were placed in the filter wall so that static pressure could be measured one inch on either side of each sand grade interface. A vane anemometer was employed to measure the flow velocity in the duct, converted to average or superficial* flow through the filter itself. Sampling ports were provided for air sampling efficiency determination. A fan was included which could operate at the expected pressure drop levels at superficial flow velocities up to 15 ft/min in the bed.

In order to duplicate the existing sand filters as closely as possible, sand and gravel was obtained from the original source and vendor (Northern Sand and Gravel Co. of Muscatine, Iowa). The specified layers of gravel and sand were placed in the test filter by hand. Table I (following text) shows the aggregate grades of sand and gravel specified for the operating Savannah River Plant filters.

Figure 2 shows the model and the graded sand levels as viewed through the transparent side of the model.

* Superficial velocity is defined as the velocity the gas would have if it were flowing through and completely filling the bed volume without any packing.

Three test series were conducted on the sand filter. Each test measured filter efficiency as a function of air velocity through the filter; pressure through the bed was monitored simultaneously. In addition to the sand loading described, tests were conducted with the same loading following compaction of the sand layers by vibration of the bed until close packing was achieved (maximum pressure drop). An overall bed compaction of $1\frac{1}{4}$ in. was achieved (figure 2). A final test condition was created by removing the top 6 inches of gravel and 12 inches of sand from the compacted bed, thus leaving 24 inches of G sand. The filtration efficiency and pressure dependence measured in the tests is shown graphically in figures 3 and 4. DOP determinations indicated that the efficiency for a "new" sand filter with a 5 ft/min velocity would be in the range of 99.95%.

The reported pressure drop is the one measured for the specific loading conditions. It was found that the ΔP could vary considerably from one bed loading to another, but the efficiency was not materially affected. However, closer packing through vibration consistently produced a 15% pressure rise at a velocity of 5 ft/min with a marginal improvement in efficiency. The importance of the G sand layer to ultimate efficiency is evident from the significant decrease in collection efficiency of the 24 inches of G sand compared to the 36 inches of G sand.

"Fiberglas" Filter Testing

Operating experience in the use of a deep bed "Fiberglas" filter unit at the Hanford Works indicated their general satisfaction with its performance. In order to provide a more direct comparison between the two types, a "Fiberglas" unit was fabricated in accordance with Hanford specifications.

Constructions of Model Unit. The filter media was purchased from American Air Filter Co. The same plywood box used in the sand filter test was used to hold the fiberglass prefilter. The prefilter consisted of 84 inches of type 115 K "Fiberglas" hand packed at 0.7 lb/ft³ for 30 inches, 1.5 lb/ft³ for 36 inches, and 3.0 lb/ft³ for 18 inches (figure 5).

A problem was encountered in attempting to achieve uniform packing density in the prefilter, especially the 3 lb/ft³ section. In this case, baling techniques developed for larger filters would prove advantageous.

The final filter assembly was mounted in a rectangular box and sealed by liberal caulking at the edges. The filter media was Corning glass type 25 & 50 "Fiberglas" matt. Suction through the filter was provided by a fan (manufactured by the Buffalo Forge Co.) which was throttled to control flow rate. Nominal operating velocities of 50 ft/min in the prefilter and 20 ft/min through the final filter assembly were maintained with 200 scfm through the model. The air intake was monitored with a vane anemometer. Sample taps and smoke introduction points were provided to permit efficiency determinations across either the prefilter, the final filter, or the combined unit.

Filter Efficiency versus Superficial Velocity. As indicated in the following table, nominal performance across the whole filter was 99.94% as determined by DOP. At 50 ft/min on initial test, an efficiency of 70% was measured across the roughing filter and 88% across the final filter with a total efficiency of 97%. It was suspected that the final filter was improperly sealed. The filter was removed, inspected, resealed, and retested. The final filter section efficiency improved to 99.88%. Since the efficiency of the prefilter was determined to be only 70% as compared with the 90% reported by Hanford, the 3 lb/ft³ material was removed and repacked. No improvement was achieved. It is felt that our method of packing was not as effective as the one used at Hanford. These difficulties probably mean that the reported efficiencies represent the low spectrum of a carefully packed filter — and they also point out the care which must be used to achieve sealing.

12th AEC AIR CLEANING CONFERENCE

Prefilter Flow, ft/min	Total ΔP , in. of H ₂ O	Efficiency, %		
		Prefilter	Final Filter	Total
27	1.35	-	-	99.95
50	3.0	65-70	99.88	99.94
130	5.0	-	-	99.92

Evaluation of Local Fine Sands

The sand for our present filters came from Iowa. Transportation costs make it economically attractive to exploit local deposits where suitable. Since the major filtration of submicron particles occurs in the G sand, vendors with sufficient deposits for supplying a filter were asked to submit samples that met the size criteria for G grade material.

Construction of Test Unit. To cut down on handling problems and sample requirements, a simple 6-inch column was constructed (figure 6). Flow was 5 ft/min, the same as in the larger model. Each of six types of sand were poured into the column and individually tested for efficiency and ΔP at various depths between 12 and 36 inches. At the completion of each test, the sand was compacted by vibration of the column and efficiency and ΔP measurements were determined again. Results (table II) indicate that Iowa G sand was significantly more efficient than the other sands tested. As would be expected, compaction slightly increased the efficiency and ΔP .

Effects of Drying on Sand Efficiency. The possibility that moisture was affecting the efficiency of the sands was also considered. Two of the local sands and the Iowa sand were dried in a furnace at 375°F for 18 hours. The sands were sealed in a container and permitted to cool and then loaded into the test equipment for retesting. Efficiency improved markedly for each sand (table III), with the Iowa sand continuing to show an advantage.

Effects of Moisture on Iowa Sand. The 18 inches of dried Iowa sand that had a collection efficiency of 99.998% was then conditioned by blowing saturated steam through it to give it 0.8% H₂O by weight. Efficiencies and ΔP measurements are shown in table III; the addition of moisture reduced the efficiency.

Chemical Analysis of Sands. After the three sands were dried, it was noted that the Iowa sand required a considerably longer period to cool. To determine possible differences in the chemical makeup of these sands an emission spectrographic analysis was performed. The results:

Columbia Silicate, S.C.

Major constituent Silica
Minor constituent None
Trace constituent None

Dawes Silica, Ga.

Major constituent Silica
Minor constituent None
Trace constituent Aluminum, iron, magnesium

Northern Sand and Gravel, Iowa

Major constituent Silica
Minor constituent Aluminum, iron, magnesium
Trace constituent Calcium, copper, manganese, sodium, titanium

[NOTE]

Major 10-100%
Minor 1-10%
Trace <1%

High Density Loading Conditions

Deep-bed filters such as the glass fiber and sand filters already described are used with the assumption that dust loading concentrations are relatively low. Conditions leading to short term, high density loadings can reduce the normal design loading life expectancy performance of the filters. In particular, an accidental fire upstream of the filter could create just such a high density loading situation. Realistic simulation of the various types of fire situations is impractical. However, a comparative test between the two filters using a model powder is a useful tool for estimating the relative effect of high density loading. A test program reported by Blasewitz, et al⁽⁴⁾, compared filter holding capacities based on tests made on several deep-bed filter designs using methylene blue powder. These tests showed the "Fiberglas" filter design, similar to that used for this test work, had greater loading capacity for a given pressure drop increase than did the model of the sand filter used at the Savannah River Plant. This work was repeated in the work described here using a model material which would more closely simulate the loading conditions which would occur as a result of an accidental fire. The number of potential fuels and burning conditions makes selection of a model powder for test purposes difficult. In making the selection, various fuels were burned in a National Bureau of Standards (NBS) combustion chamber, with the particle size distribution of the products of combustion measured by the Cascade Impactor shown schematically in figure 7. Particle sizes generated by two burning conditions (pyrolytic decomposition with heat and open-flame combustion), simulating smoldering and full burning conditions, respectively, were determined. Neoprene gloves, vinyl tile, "Benelex," vinyl garden hose, "Lucite" plastic, and "Ultrasene" (30.2% tributyl phosphate) were the fuels selected. The size distribution of the smoke particles that resulted is shown in figures 8 and 9. A carbon black "Raven 15" manufactured by Columbian Carbon Co. was selected as the model powder. Figures 8 and 9 show the size distribution of the model material dispersed by a pneumatic eductor as compared to the various fuels. The model powder includes the full particle size spectrum, but it is not necessarily representative of any specific surface characteristics of such products of combustion.

Experimental Procedure for Loading of Sand and "Fiberglas" Filters

The deep-bed "Fiberglas" and sand aggregate filters described schematically in figures 1 and 5 were tested under conditions simulating high smoke loading conditions. The respective filters were operated under normal flow rates, giving velocities of 50 and 5 fpm in the "Fiberglas" and sand. The carbon black powder was fed directly into the supply plenum using a pneumatic injector for metering and dispersing (figure 10). The rate of feed was measured on a weight basis. Total pressure drop across the filter beds at critical interfaces between bed levels was continuously monitored. Figure 11 shows the weight (g) of powder fed plotted against time. The injection rate to the "Fiberglas" filter was increased to adjust for the 10-fold greater total flow for the same cross-sectional area. Carbon black was fed until the ΔP of each filter reached 15 in. of water.

Sand Filter Loading. Figure 12 shows pressure rise in the filter bed as a function of the weight of carbon black injected. The distribution of pressure in the bed is shown for the bed locations 1 in. above the E-F interface and 1 in. above the C-E interface. Pressure drop in the G sand layer remained constant through the test series. Figure 13 contains photographs of the E-F interface taken early in the

test and at its conclusion. Upon completion of the test, the sand in G layer was removed, revealing approximately 3 in. deeper black powder penetration at the center of the bed than at the walls. Approximately 6 oz of carbon black was retained in the filter plenum. The E-F interface proved to be the pressure limiting bed region for collection of this model material. These results correlate the work done at Hanford⁽⁴⁾ in tests on similar bed constructions using methylene blue powder. In these tests, a critical loading condition was reached which caused an exponential rise in pressure with model smoke addition.

"Fiberglas" Filter Loading. Figure 14 shows the pressure history in the prefilter and final filter elements of the "Fiberglas" filter when subjected to the smoke simulation test conditions. The pressure drop across the filter elements and at the interface between layers packed to densities of 0.7 lb/ft³ and 1.5 lb/ft³ is also shown. These curves clearly show that as each density layer becomes loaded, any additional material added to the filter flows into the next more dense section of the filter. Examination of the filter media upon completion of the test showed that the carbon black collected on the walls extended further into the filter than the black in the middle of the bed, indicating bypassing at the walls with such bed construction. Figure 15 shows how, at the conclusion of the test, the veins of black penetrated the 18-inch layer packed at 3 lb/ft³

Relative Filter Performance

The pressure history across the respective model filters as a function of pounds of carbon black/scfm/ft² of bed area is shown in figure 16. This figure provides a comparison of the holding capacities of the two beds operated under equivalent conditions. On this basis, the sand filter held more "smoke" over a total ΔP of 15 inches than the "Fiberglas" bed did. The work by Blasewitz et al with methylene blue loadings showed generally comparable trends but showed greater holding capacity for the "Fiberglas" compared to the sand filter. [Their tests assumed a total pressure increase of 5 inches of water caused pluggage.]

In this work, "new" clean filters were used in all tests. It is apparent that the net effect of any high loading condition, in terms of total life, is dependent upon loading conditions prior to the event. Late in the life of the filter, even minor accidents could cause significant increases in ΔP . While work with model material may not represent actual conditions, it provides a useful guide for comparison of filters and estimation of their useful life.

While these tests do not provide any marked differences between sand and "Fiberglas" filters when considering filtrations of combustion products, they do provide a benchmark for use in estimating life expectancy under various hypothetical conditions. One point which the tests did not cover was the relative efficiency of the filter during loading. In general, it may be concluded that bed loading is a function of packing density and higher efficiency, but our work indicates that this may not always be true. If a sand filter operates at 5 ft/min, the collection mechanism is largely gravitational so that within the operating pressures discussed, efficiency should not be impaired. However, the "Fiberglas" filter operates on the principle of impaction and diffusion so that efficiency for any given layer can increase or decrease throughout filter life. The net effect is not easily predicted, but in the practical operating range, efficiency is not likely to be impaired. Under normal operating conditions, one would probably pick some optimum life considerably shorter than the time required to achieve full bed loading. This, of course, does not allow for a fire incident which would seriously reduce filter life. It should also be noted that even a plugged filter may still have utility at reduced flow rates.

Table IV gives a comparison between the models of sand and "Fiberglass" filters which were tested. The information was taken from data reported in this paper and it provides a relative reference to the gross operating performance of filters under new conditions.

Conclusion

Ideally, a filter designed for collection of radioactive off-gases should have infinite efficiency in particulate collection, extremely long operating life, and operate at very low pressure resistance. Unfortunately, these criteria are not compatible with one another, so compromises are required. The correct ordering of safety and cost priorities must, of course, be dictated by the application. The following is a compilation of some general observations made from the operation and results of the tests.

<u>Sand Filters</u>	<u>"Fiberglas" Filters</u>
<u>Advantages</u>	<u>Advantages</u>
<ul style="list-style-type: none"> o Are relatively self-sealing o Have efficiency that improves with life (to point of breakthrough) o Are of proven design 	<ul style="list-style-type: none"> o Operate at relatively low pressure o Have design flexibility that reflects on collection efficiency o Have life status that is more easily predicted
<u>Limitations</u>	<u>Limitations</u>
<ul style="list-style-type: none"> o Have little design flexibility within cost and efficiency limits o Require higher operating pressure o Require larger filter area o Have life that is more difficult to predict 	<ul style="list-style-type: none"> o Can bypass or leak o Can have variable efficiency performance o Present greater design challenge o Are dependent upon quality control in filter media manufacturing

References

1. R. A. Juvinall, R. W. Kessie, and M. J. Steindler, "Sand-Bed Filtration of Aerosols: A Review of Published Information on Their Use in Industrial and Atomic Energy Facilities." Argonne National Laboratory report ANL-7683 (1970).
2. D. R. Mc Fee and J. Sedlet, "Plutonium-Uranium-Molybdenum Fume Characteristics and Sand Filtration." *Journal of Nuclear Energy*, 22, pp 641-650 (1968).
3. A. G. Blasewitz and B. F. Judson, "Filtration of Radioactive Aerosols by Glass Fibers." *Chemical Engineering Progress*, 51, pp 6-j-11-j (1955).
4. A. G. Blasewitz, R. V. Carlisle, B. F. Judson, M. F. Katzer, E. F. Kurtz, W. C. Schmidt, and B. Weidenbaum, "Filtration of Radioactive Aerosols by Glass Fibers." General Electric Co., Hanford Works, HW-20847, Vol 1 & 2 (1951).

12th AEC AIR CLEANING CONFERENCE

TABLE I. SAND FILTER MATERIALS

Gravel Type

A	0% retained in 3" screen; less than 2% passing 1-1/4" screen
B	0% retained on 1-1/2" screen; less than 2% passing 5/8" screen
C	0% retained on 5/8" screen; less than 5% passing 1/4" screen
E	Less than 1% retained on 1/4" screen; less than 5% passing 8 mesh screen

Sand Type

F	Less than 5% retained on 8 mesh screen; less than 5% passing 20 mesh screen
G	Less than 2% retained on 20 mesh screen; 20-40% retained on 30 mesh screen. Less than 1% fines and dirt passing 50 mesh screen

TABLE II. DOP EFFICIENCY TESTS FOR G SAND

Vendor	Sand Depth, in.	Relative Humidity of Air, %	AP, in. of H ₂ O	Efficiency, %
Northern Sand and Gravel, Iowa	12	65	1.3	99.0
	24	65	1.6-1.9	99.95
	36	65	2.4-2.6	99.97
	33-7/8 (close packed)	65	2.8-3.0	99.98
Columbia Silica, Georgia	12	65	0.6	82.0
	24	65	1.2	97.5
	36	65	~3.0	98.2
	36 (close packed)	65	~3.0	99.25
Dawes Silica, Georgia	24	65	1.5	99.80
	36	65	2.1	99.92
	36 (close packed)	65	2.5	99.95
Unisil Silica, Minnesota	24	65	1.8	99.7
	24 (close packed)	65	2.25	99.9
Ottawa Silica	24	65	1.7	99.5
	24 (close packed)	65	2.1	99.8
Sans Saba, Texas	24	65	1.6	99.7
	24 (close packed)	65	2.0	99.8
Repeat Test				
Northern Sand and Gravel, Iowa	24		1.6	99.95
	36		2.4	99.97
	36 (close packed)		2.8	99.98

12th AEC AIR CLEANING CONFERENCE

TABLE III. HUMIDITY versus EFFICIENCY

Vendor	Sand Depth, in.	ΔP , in. of H ₂ O	Effi- ciency, %	Condition
Northern Sand and Gravel, Iowa	18	1.9	98.3	Air at 30% relative humidity (as received)
	18	1.75	99.998	Dried by heating at 375°F for 18 hr
	18	1.75	98.2	Saturated with steam
Columbia Silica, South Carolina	18	0.94	92	Air at 30% relative humidity (as received)
	18	0.8	99.6	Dried by heating at 375°F for 18 hr
Dawes Silica, Georgia	18	1.5	98	Air at 30% relative humidity (as received)
	18	1.5	99.85	Dried by heating at 375°F for 18 hr

TABLE IV. CHARACTERISTICS OF SAND
AND "FIBERGLAS" FILTERS

	Savannah River Sand Filters	Hanford Works "Fiberglas" Filters
Superficial velocity, fpm	5	50
Pressure across filter media, in. of H ₂ O	4.8	2.7
Scfm/ft ² of filter area	5	50
Lb filter media/scfm	160	0.23
DOP efficiency, %	99.95 ± 0.02	99.94 ± 0.03
Smoke capacity, lb/sq ft (to 15 in. of H ₂ O)	0.74	4.5
Smoke capacity, lb carbon black/cfm	0.15	0.09

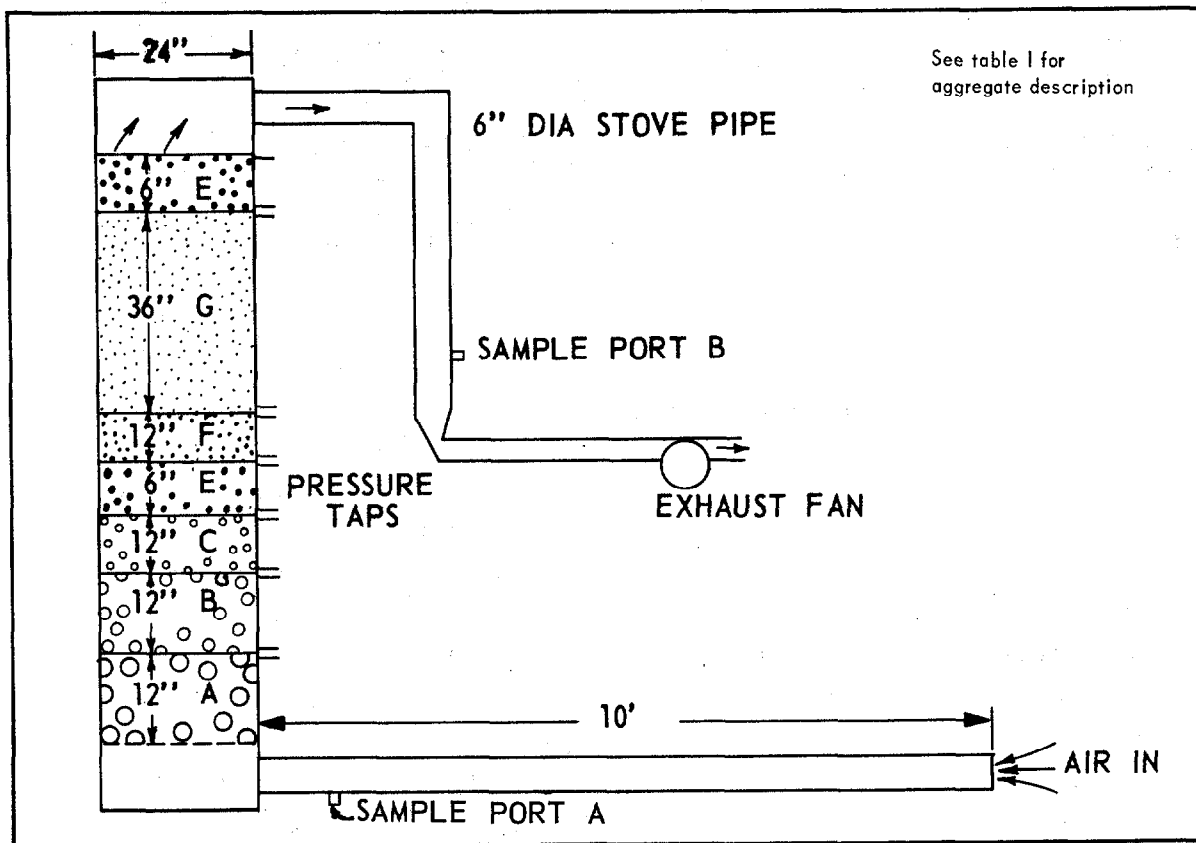


FIGURE 1. SAND FILTER TEST APPARATUS

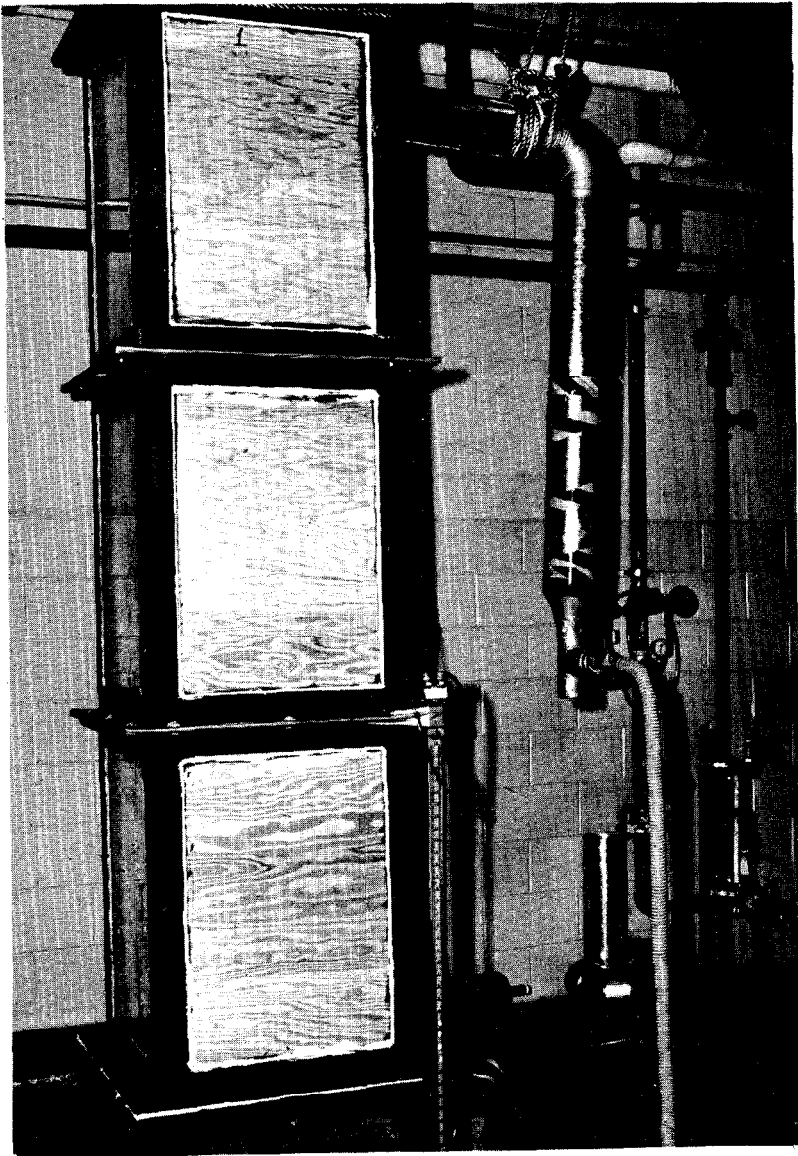


FIGURE 2A. SAND FILTER MODEL

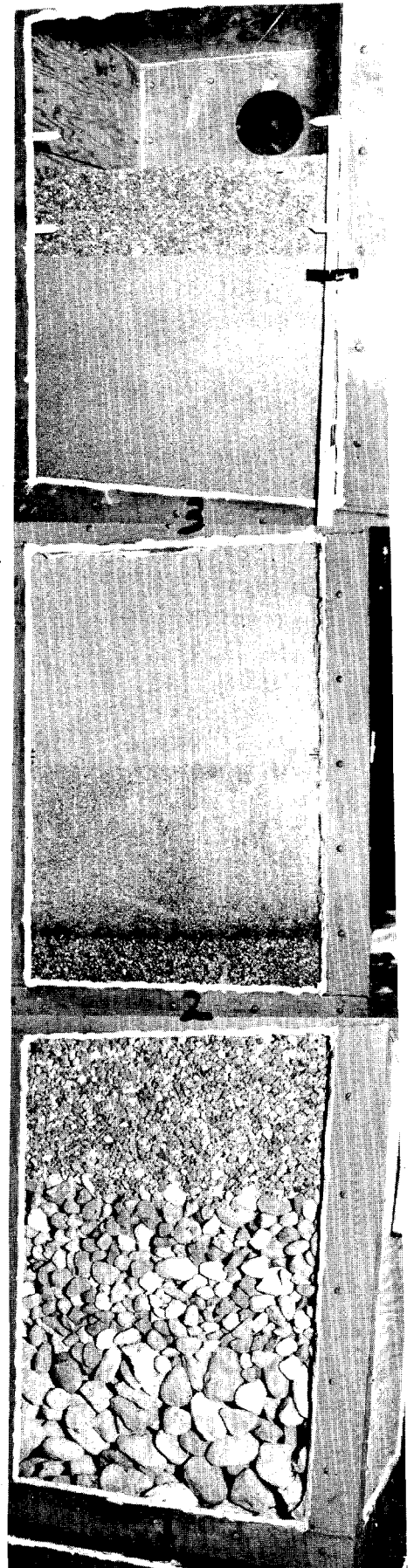
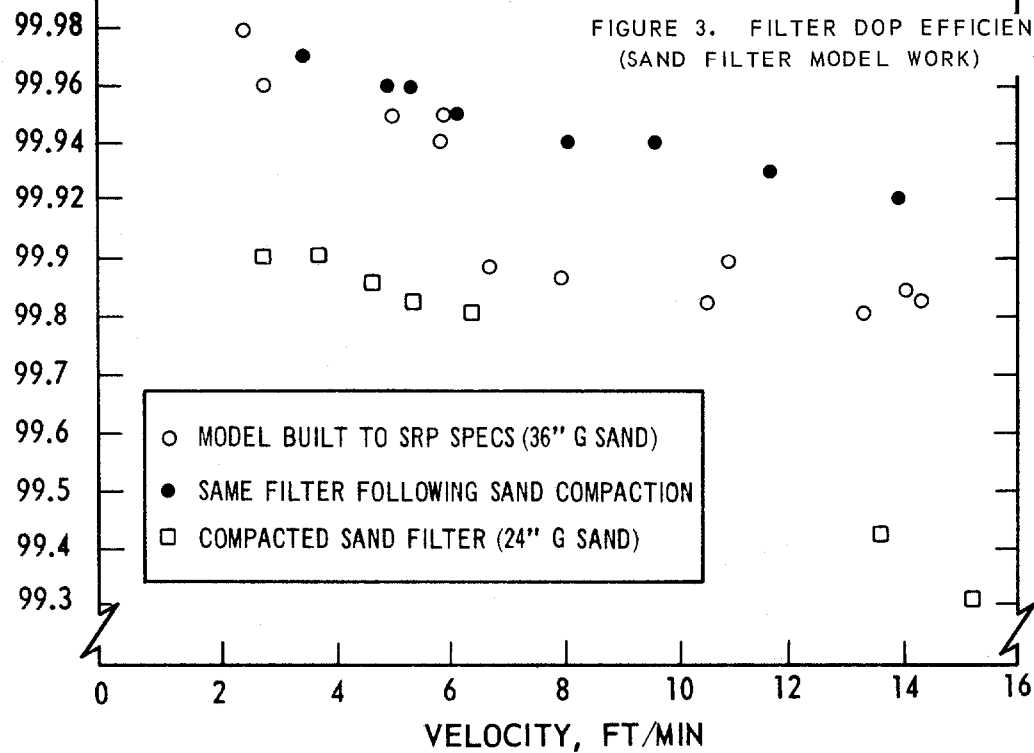


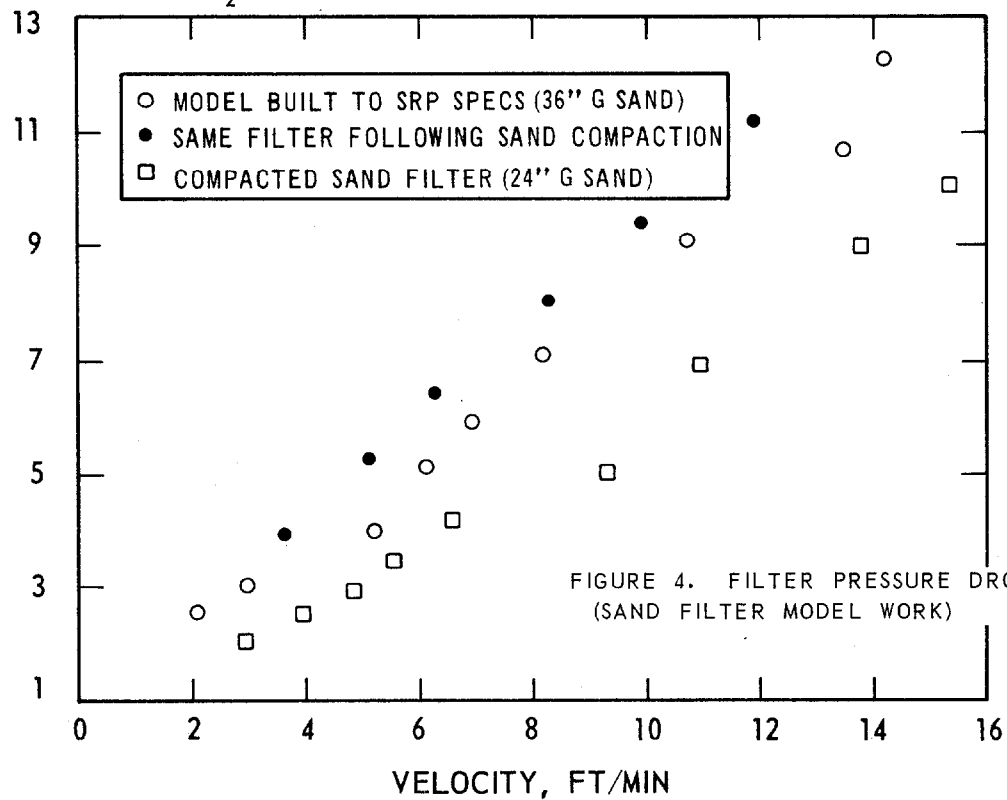
FIGURE 2B. GRADED SAND LEVELS
SHOWING COMPACTION AFTER
VIBRATION

DOP EFFICIENCY,
 η (PERCENT)

100.0



PRESSURE DROP,
INCHES OF H₂O



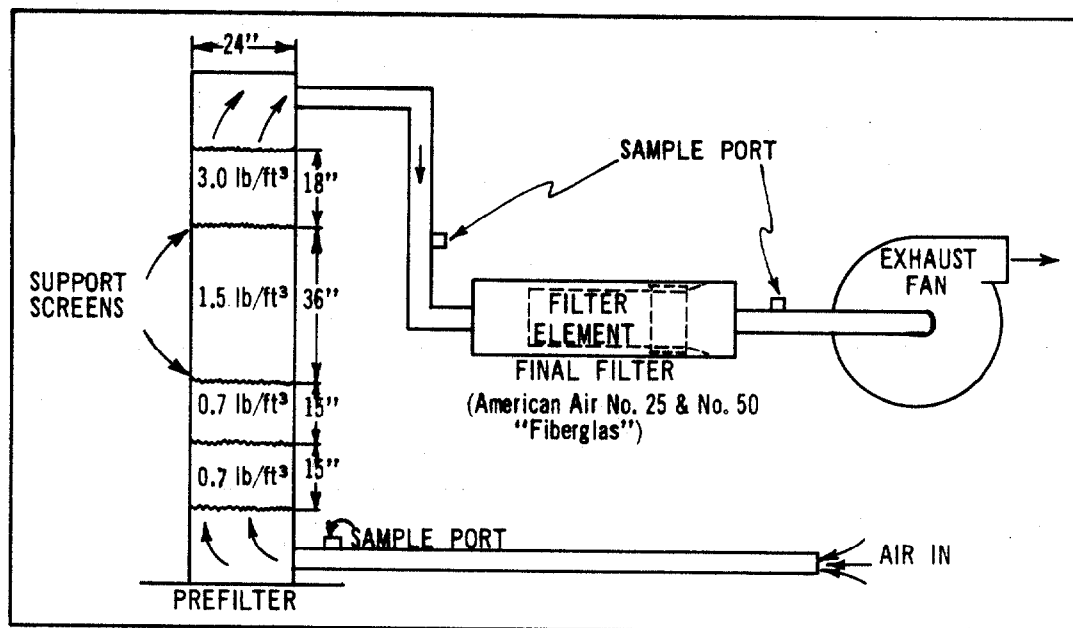


FIGURE 5. "FIBERGLAS" FILTER MODEL

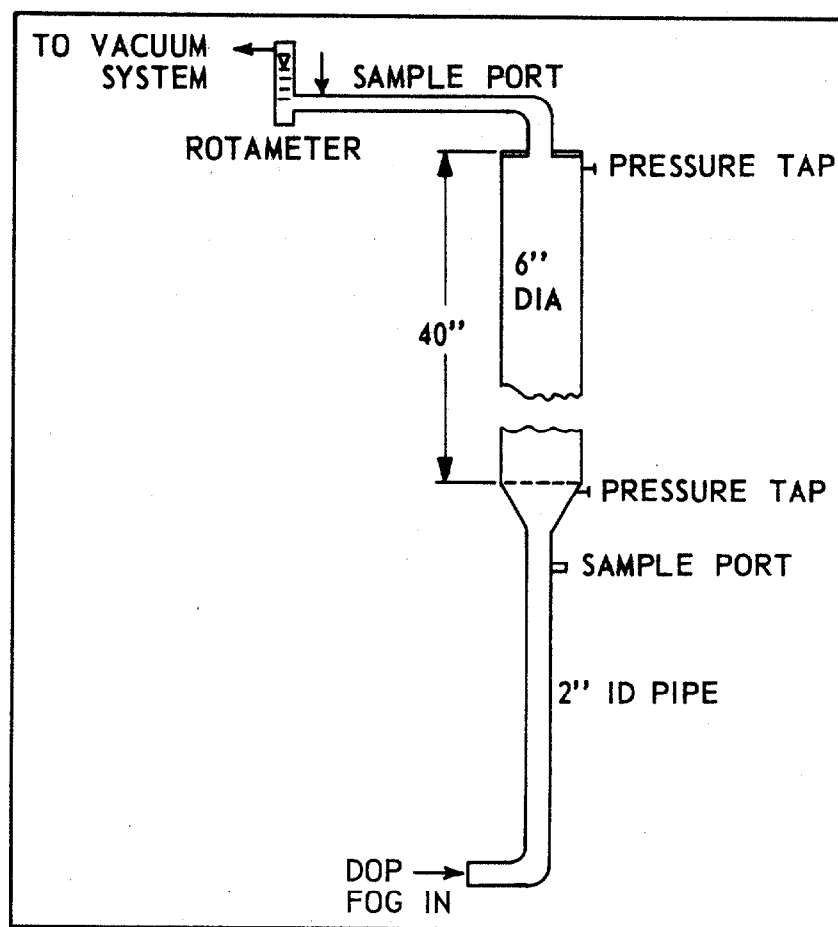


FIGURE 6. EFFICIENCY TEST APPARATUS FOR G SAND

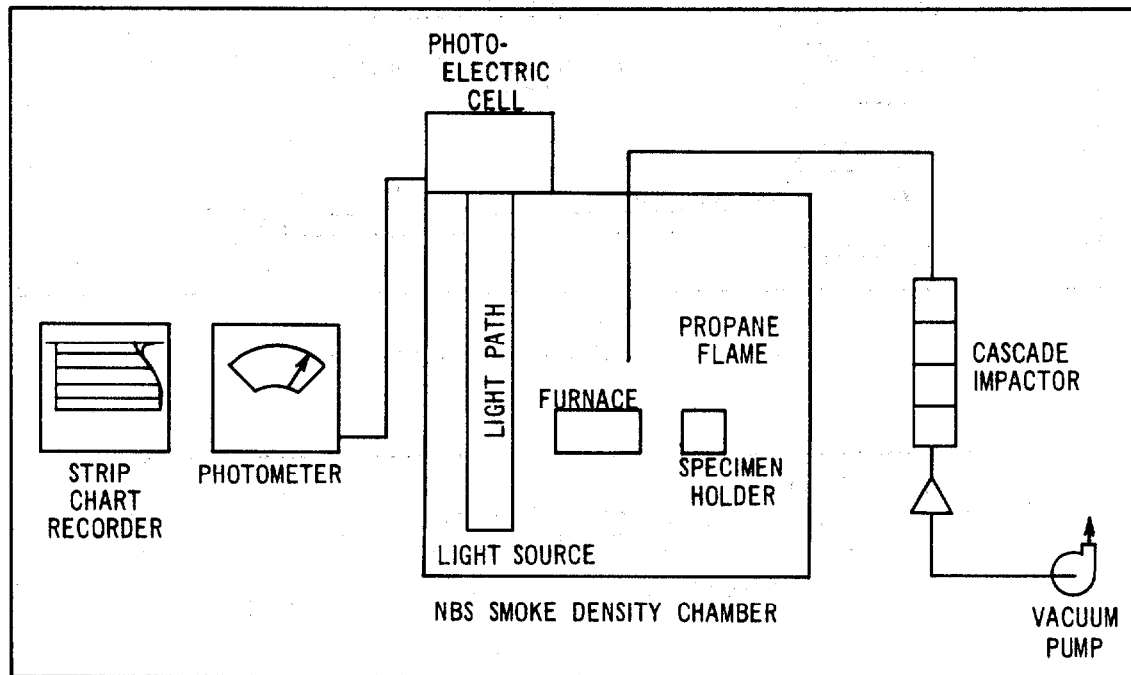
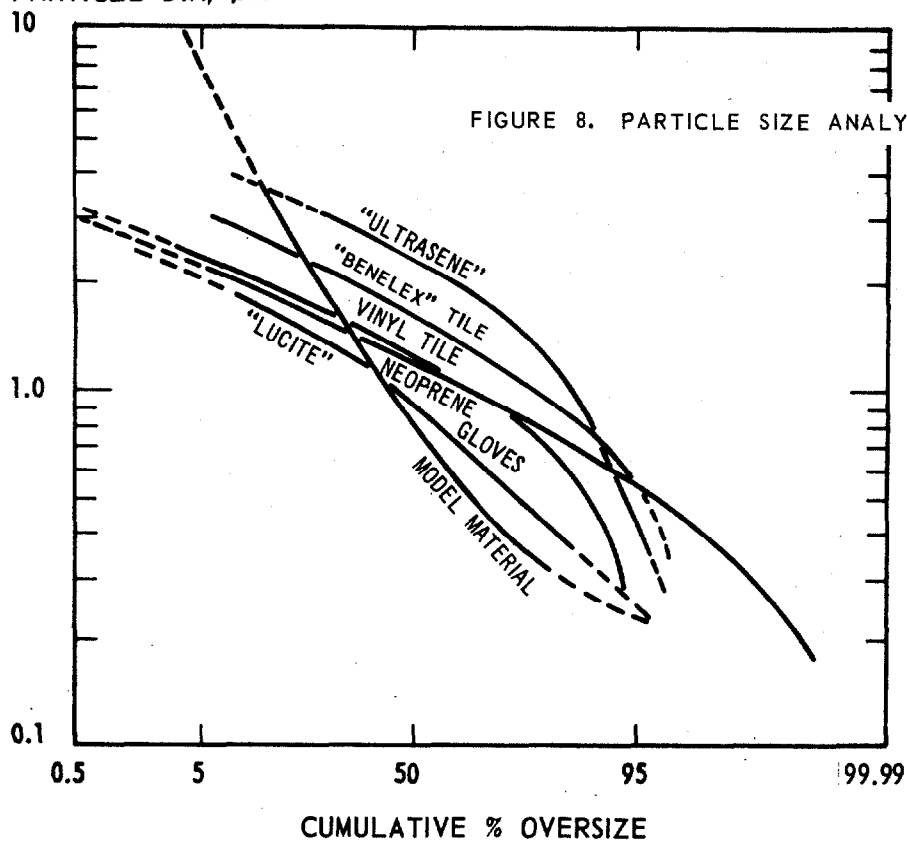
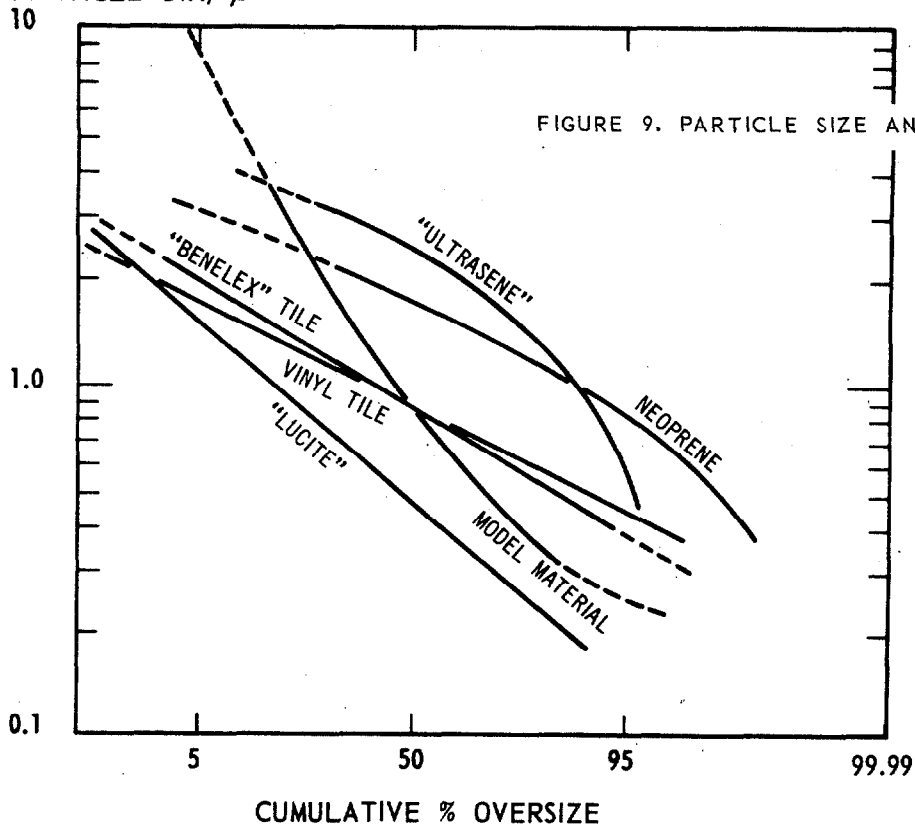


FIGURE 7. SETUP FOR FILTER HOLDING CAPACITY TESTS

PARTICLE DIA, μm



PARTICLE DIA, μm



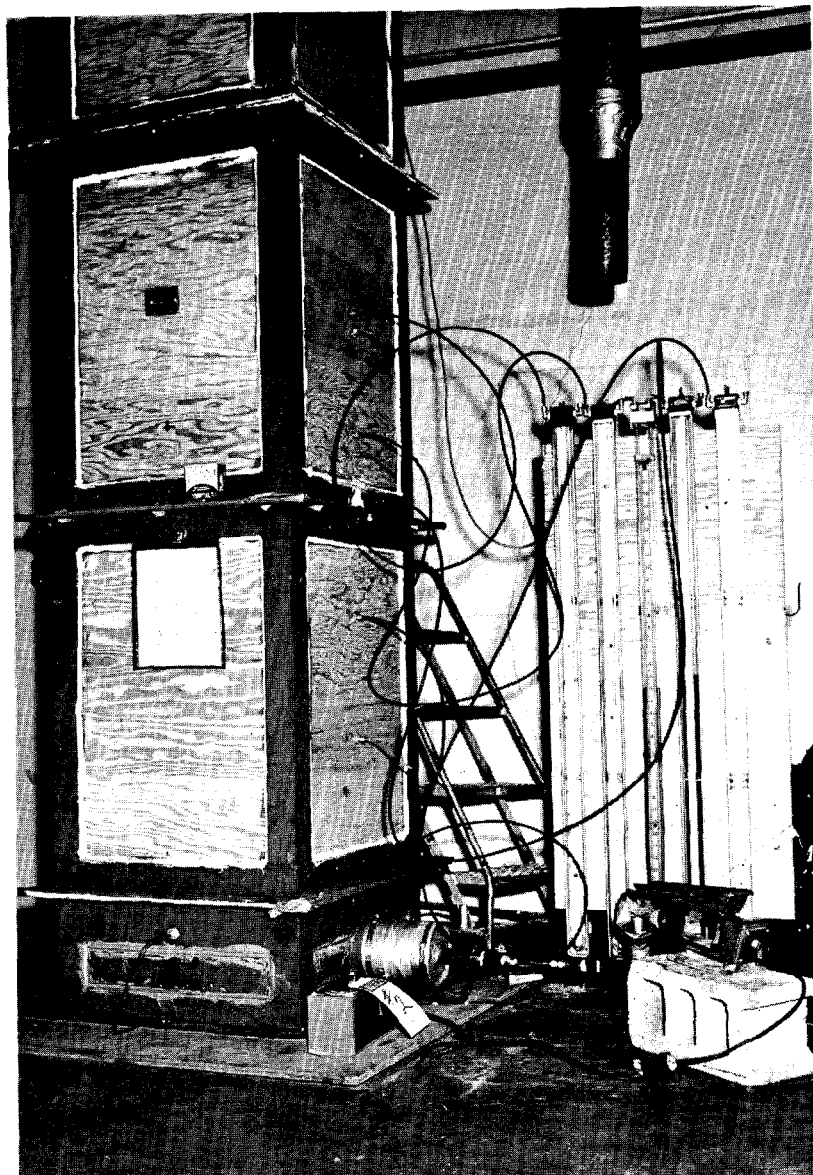


FIGURE 10. PNEUMATIC INJECTOR FOR METERING CARBON
BLACK TO FILTER

FIGURE 11. RATE OF INJECTION OF CARBON BLACK

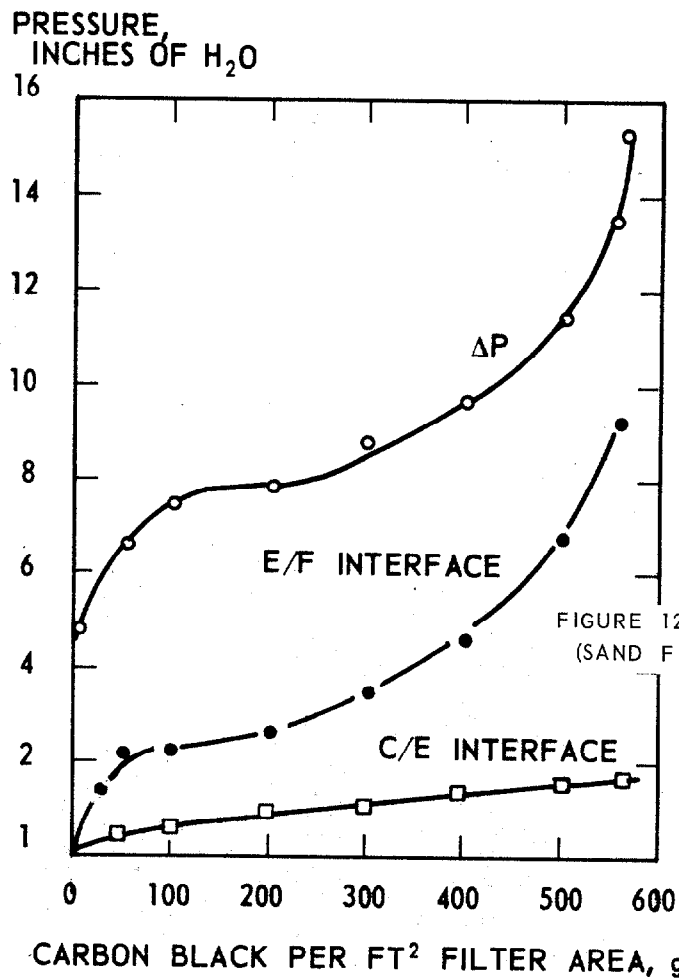
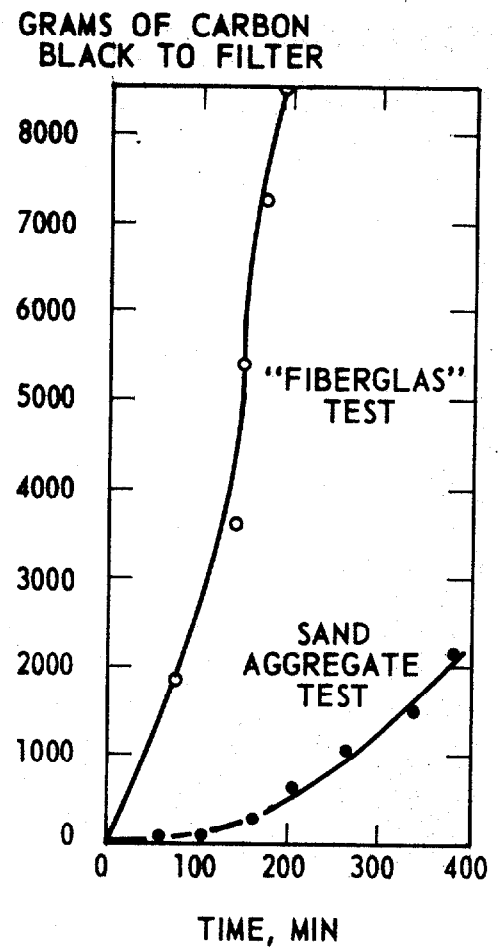


FIGURE 12. PRESSURE VERSUS GRAMS OF CARBON BLACK (SAND FILTER SMOKE SIMULATION)

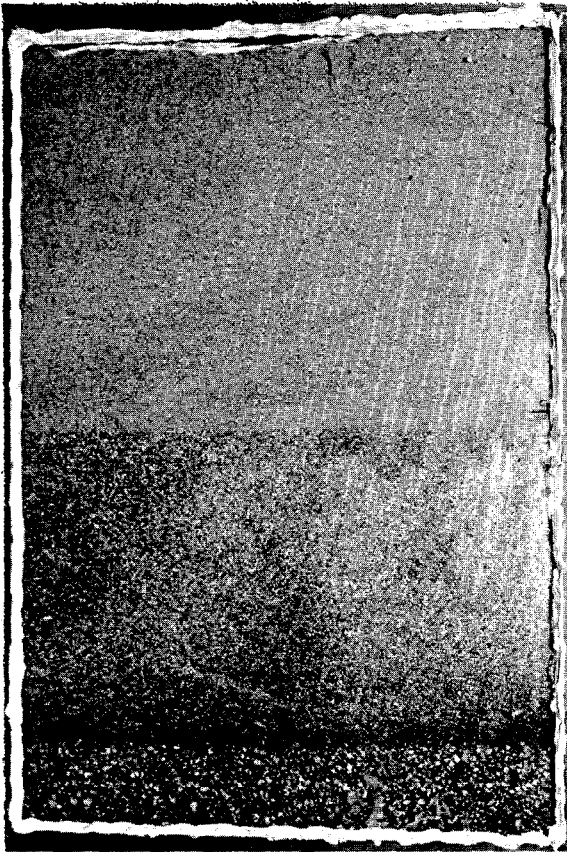


FIGURE 13A. CARBON BLACK DEPOSITS EARLY IN TEST

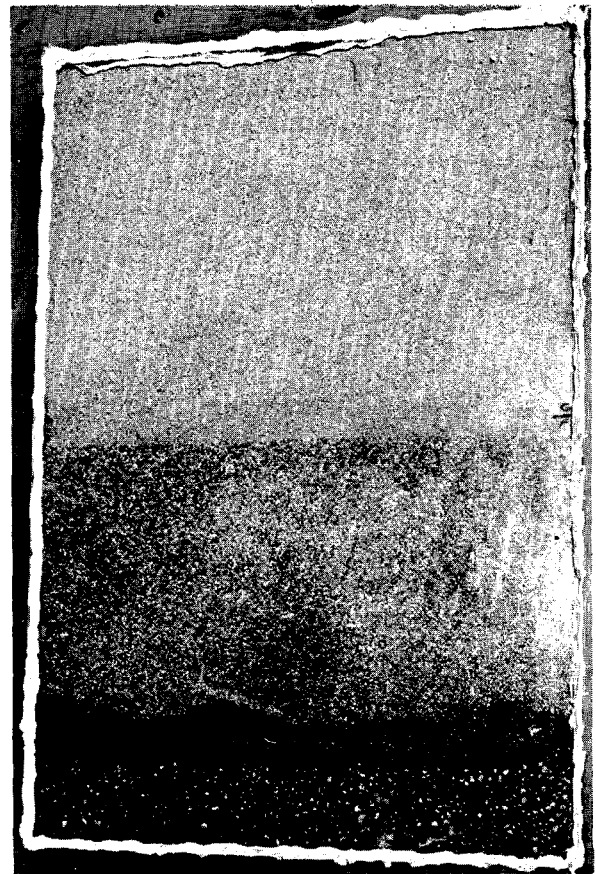


FIGURE 13B. CARBON BLACK DEPOSITS
AT END OF TEST

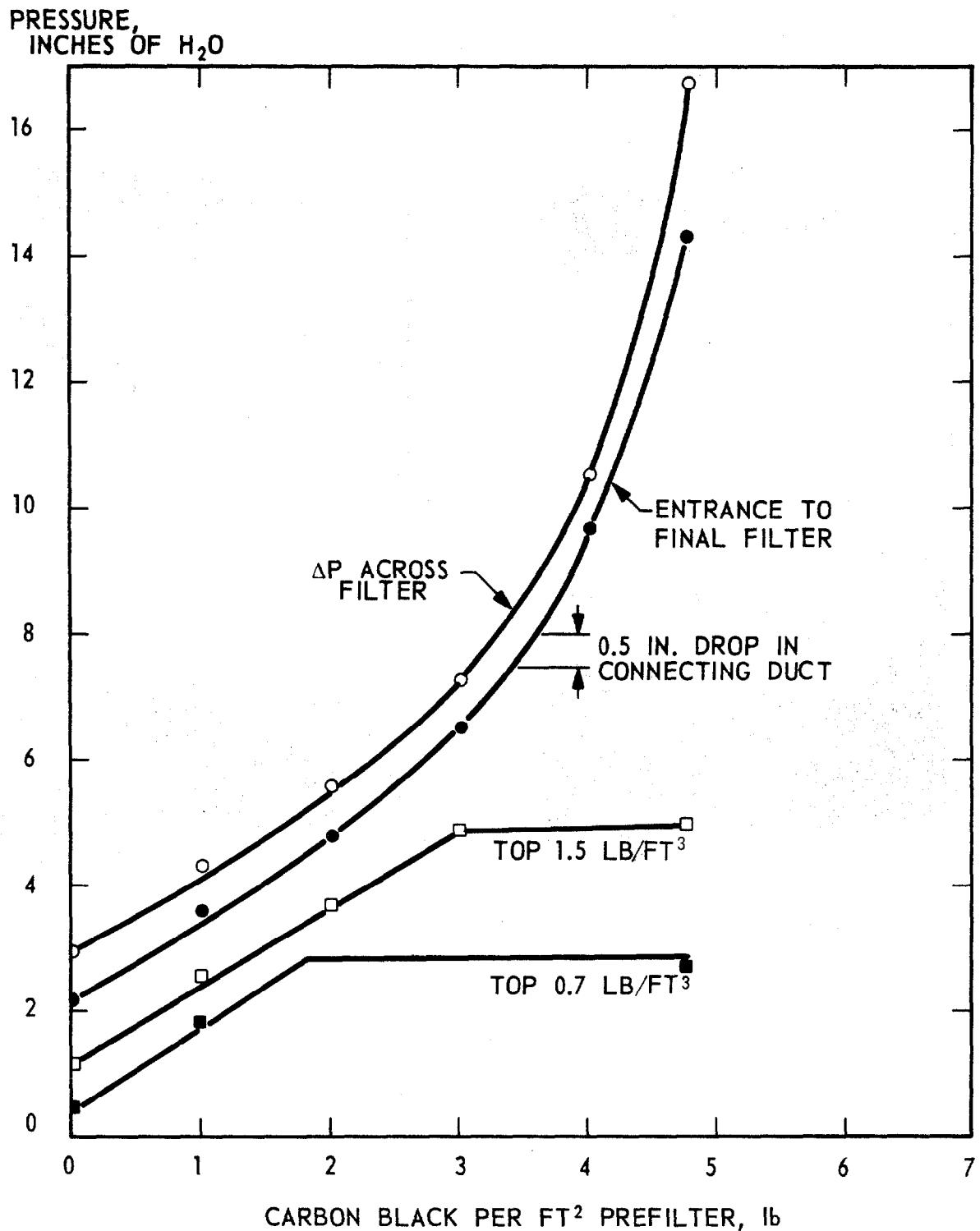


FIGURE 14. PRESSURE VERSUS POUNDS OF CARBON BLACK
("FIBERGLAS" FILTER SMOKE SIMULATION)

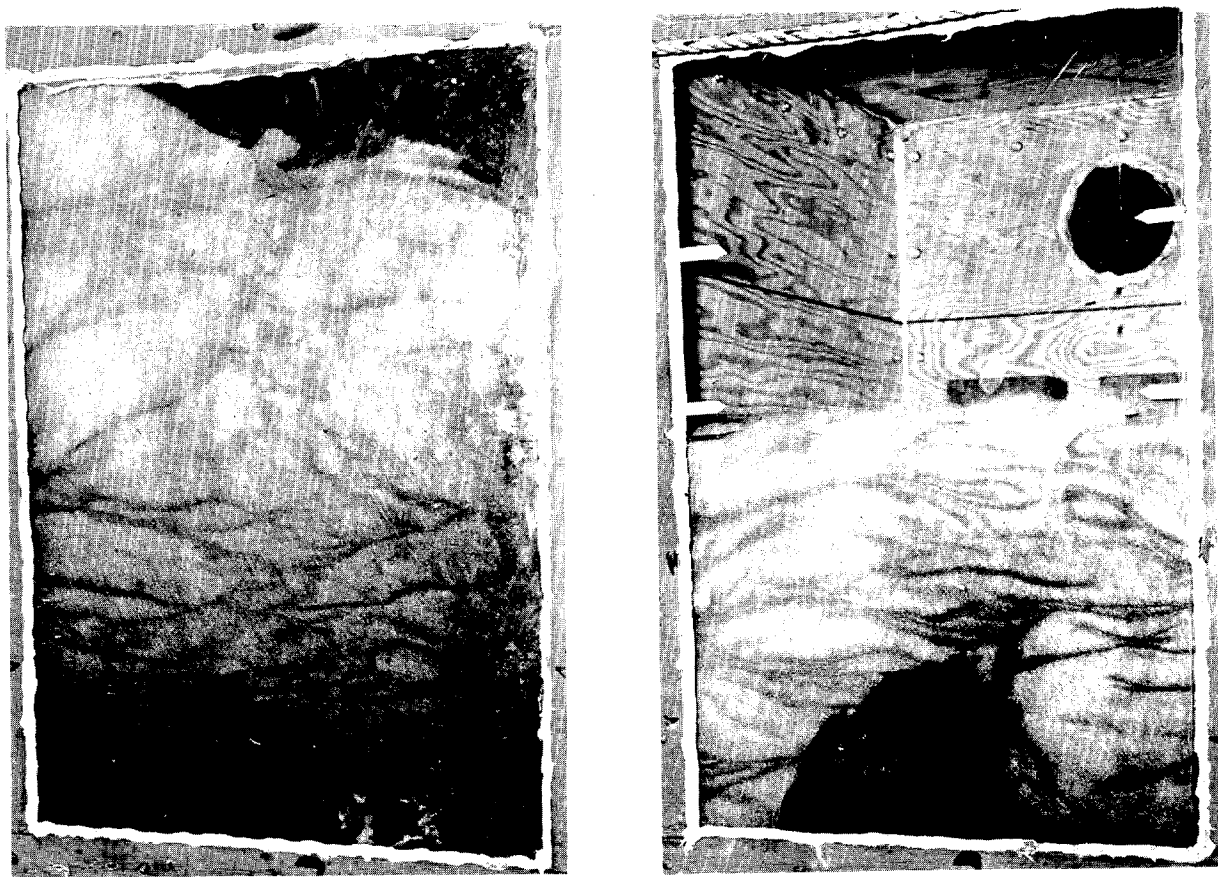


FIGURE 15. PENETRATION OF CARBON BLACK AT COMPLETION OF TEST

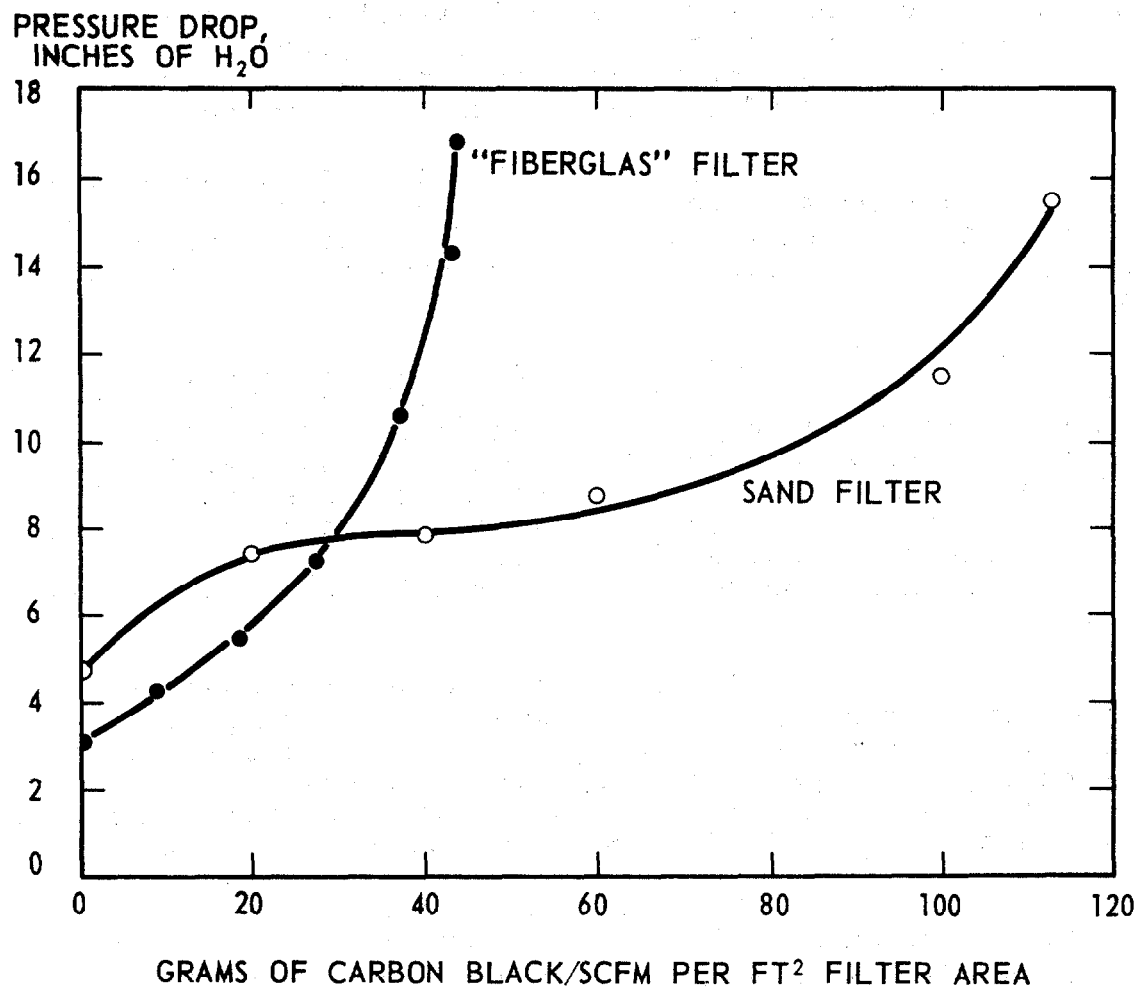


FIGURE 16. SMOKE SIMULATION COMPARISON BETWEEN SAND AND "FIBERGLAS" FILTERS

DISCUSSION

ETTINGER: In the introduction to your paper, you indicated that the experience with sand filtration at Savannah River includes extensive data about very high sand filter efficiency in qualitative terms. I wonder if you have any quantitative data covering the efficiency of the sand filters at Savannah River.

ZIPPLER: Efficiency is based on air samples taken upstream and downstream of the filter. These measurements indicate 99.97 to 99.98% for normal operations. These tests were not performed with 0.3 or 0.7 μ m aerosols. This was one reason for the test I described.

THOMAS: As some of you probably know, Bob Yoder and I did some work on sand filters here at Oak Ridge about 15 years ago. We found that the efficiency of the bed is considerably higher if the air flow is downwards into the filter rather than upwards. This work was published about 1956 in the AMA Archives Industrial Health, I believe. But everybody seems to be doing it the other way; in other words, using up-flow. There may be good reason for this, but as the bed is more efficient for down-flow, I would like to know what that reason is.

RAY: I believe the reason for up-flow being preferred in this country is because down-flow filtering experience, particularly that reported in the Russian literature, indicates that filter clogging develops relatively early. Mechanical raking is used to relieve excessive filter resistance, but this relief gradually deteriorates and is limited after repeated rakings.

YODER: On your steam tests; after you dry your filters and put steam back in, how much steam or moisture is collected in the filter? Did you see any evidence of plugging in the filter or condensation in the filter.

SCHURR: In that particular test we were primarily interested in what happens when the filter gets wet. There are two types of mechanisms for getting a filter wet. One is from moisture additions from the top of the up-flow filter. The other is from condensation or moisture being brought in by the air, in which case, we essentially saturated the filter. If I recall the data correctly, the pressure drop did rise slightly. The efficiency was comparable, or perhaps even better, in a wet filter where the moisture is brought up in the entrained air.

BOYD: About 15 years ago I sampled a Hanford Filter for two years and observed efficiencies from 97% to as high as the values that have been indicated for the fiber glass filters. An efficiency of 97% was observed when the input to the filter was very, very low in microcuries. When the input to the filter was high,

efficiency increased. I believe the reason for this was a change in particle size of the contaminant stream going into the filter.

SCHURR: Although we like to use the term efficiency, I think we have to keep in mind that efficiencies are relative numbers based upon either the effluent gas being filtered or the filtration test used for comparison. The numbers we are reporting relate to generated DOP smokes and do not necessarily correlate with any of the particulate matter that might be handled by an on-stream filter. I think you have to be very careful to define what type of smoke you are filtering when you are comparing numbers.

BARLOW: We wondered if the sand filter was used for waste incineration? If so, have you any data on its use in a cold climate?

SCHURR: I am sure we have no data that relate climate factors to filtration. We have some evidence that climate may cause perturbations over some normal operating condition.

ZIPPLER: We have seen some slight variation in the efficiency of the filter over the year depending upon whether it is winter or summertime. The primary difference we have seen has been in the resistance measurement.

ADEQUACY OF VENTILATION EXHAUST FILTERING SYSTEM
FOR NEW PLUTONIUM FACILITIES*

Nils Hetland, John L. Russell Jr
C F Braun & Co
Alhambra, California 91802

Abstract

As a part of the conceptual design studies for a New Plutonium Recovery Facility for the AEC Rocky Flats Plant, a special study was made to determine the requirements for adequate ventilation exhaust filtering systems. The new AEC Minimum Criteria for New Plutonium Facilities, dated April, 1971, establishes some very stringent requirements for such ventilation systems. This new criteria requires that concentrations of soluble plutonium in the exhaust gases at the exit from the building shall not exceed the allowable limits set forth in AECM 0524, and that the exhaust ventilation systems providing confinement shall continuously perform throughout the design basis accidents that can be postulated for the facility, including those resulting from natural phenomena such as earthquake and tornado. This study was accomplished in three steps. The first was a study of existing systems. The second consisted of mathematically analyzing model systems, one based on data from similar operating systems, and one based on recent theory. The models were compared. The third step consisted of developing systems having comparable decontamination capabilities using HEPA and deep-bed sand and fiberglass filters. These were compared for cost and safety. Considerations included the nature and characteristics of the plutonium aerosol, the mechanics of filtration, corrosives in the exhaust stream, filter fire protection, system earthquake resistance, tornado protection, maintainability and reliability. It was concluded that filtering systems can be built to provide the necessary decontamination factors on a continuous, reliable and safe basis, with adequate fire protection and protection from earthquake and tornado forces. It was also concluded that there is a lack of direct operating data with plutonium that can be applied for design purposes, and that a program of testing and recording of actual operating data is necessary.

*The information contained in this article was developed during work under Contract AT(29-2)-2996 with the U S Atomic Energy Commission.

Introduction

This work is an integral part of an overall design effort for a large capacity plutonium recovery facility. The purpose was to apply the most currently applicable technology and experience to the design engineering of exhaust systems confining the radioactive aerosols generated in processing operations, and to provide every possible assurance that both the internal and external environment related to this facility were protected from uncontrolled contamination. This overall effort is still in progress, and some of the solutions found herein may not be the final ones.

Background

In April of 1971 the United States Atomic Energy Commission (AEC) initiated a Study of Alternatives to determine the most economical and effective way to replace the Plutonium Recovery Facility, Building 771, at their Rocky Flats Plant. Plutonium -239 is the principal material involved in the processing in this facility. Plutonium isotopes -238, -240, and -241, and Americium -242 are encountered in very small quantities.

A requirement of this effort was to develop designs for effluent control systems. Such designs, as a minimum, should satisfy the requirements of the new AEC Minimum Criteria for New Plutonium Facilities, dated April 1971.

This new criteria requires that concentrations of radioactive and noxious materials in the exhaust, measured at the release point from the building, shall be kept to the lowest practicable levels commensurate with present day technology. The team involved in this effort interpreted this as meaning that under no predictable circumstances shall radioactive material concentrations in the building exhausts exceed the allowable limits set forth in the AEC Manual 0524. These allowable limits of concentration in air for the materials involved are:

Pu -238	7×10^{-14}	pCi/ml
Pu -239	6×10^{-14}	pCi/ml
Pu -240	6×10^{-14}	pCi/ml
Pu -241	3×10^{-12}	pCi/ml
Am -242	1×10^{-9}	pCi/ml

The new criteria further requires that the exhaust ventilation systems providing confinement shall continuously perform throughout the design basis accidents that are postulated for the facility. Accidents analysis shall consider internal events such as fires and explosions, and shall include those accidents resulting from natural phenomena such as earthquakes and tornados.

Those more stringent requirements, plus the operating experience from the existing facility, necessitated a study of the design ventilation systems for decontamination adequacy and operating safety and reliability.

Procedure

This study was accomplished in three steps. The first was an on-site survey of ventilation systems in existing plutonium processing facilities. Facilities visited included the Argonne National Laboratory, the Savannah River Plant, the Oak Ridge Plant and National Laboratory, NUMEC, Inc. (a commercial venture), Mound Laboratory, Hanford facilities, and the Los Alamos Scientific Laboratory. Items looked for included the basis of design for parameters such as the ventilation rates and decontamination factors, operating safety features such as fire protection, redundancy of equipment, monitoring and alarm philosophy, and special features for effective maintenance and performance evaluation testing.

The second step consisted of analyzing an existing filtering system from performance data, and then a model based on recent filtration theory using the same loading rate. Results of these analyses were compared to determine if actual performance data and theory showed any similarity.

The third step consisted of an analysis of the hazards which might cause an excessive release of plutonium from a system. Considered were

- Normal Operation
- Fire and Smoke
- Explosion
- Earthquake
- Tornado
- Other

A literature search was conducted on all these safety engineering aspects of filtering systems. Persons doing current testing and research in these areas were also contacted to assure that we had considered the most current thinking and experience.

From the results of the work in these three steps two model systems were developed which appeared to merit full analysis and comparison.

These were

- 1 A system using only HEPA (High Efficiency Particulate Air) filters.

- 2 A system using a series combination of HEPA and deep-bed (sand or fiberglass) filters.

The cost differences between these systems were estimated for comparison.

Analysis

The site investigations were very valuable in establishing guidelines for the detailed systems analyses. This effort provided a background as to the various types of systems in use, and an indication of the advantages and disadvantages of different design features currently in use.

The following beneficial design practices were noted

- 1 Most systems were designed to confine the radioactive aerosols as close to the point of origin as was practicable.

- 2 Process vent collection systems were installed where process generated fumes and vapors were encountered. Such systems consisted variously of reflux condensers, demisters, and scrubbers. This protected the ductwork and final filters from exposure to wetting or deleterious chemical attack.

- 3 A HEPA filter was installed at each glovebox exhaust connection. This was not normally a testable installation but it did effectively remove most of the aerosol generated in a box. This greatly reduced the loading at the final filters. It also prevented the build-up of combustible dirt within the exhaust ductwork. Investigation at Oak Ridge has shown that the propagation of flame through ductwork is greatly inhibited where the ducts are kept free of an accumulation of combustible dirt.

- 4 Fire protection sprinklers were installed where there were large multiple filter banks. Where this was not practical, spark and flame arresters and isolation valves were installed.

12th AEC AIR CLEANING CONFERENCE

5 Where continuous operation was essential to safety, stand-by fans were provided. In some cases stand-by filters were installed, usually to facilitate change-out.

6 In all cases surveyed filter systems were found to be meeting or exceeding decontamination requirements. Most often a single stage of HEPA filters was found to be adequate. In some cases a second stage was provided for back-up. In a few exceptional cases, where larger quantities of material were involved, as in chemical processing type operations, from three to six series HEPA filters were provided. Some systems additionally relied on dilution to meet effluent limits.

• 7 Testability of the filtering system in-place was considered an essential safety feature.

It was determined that the most directly applicable experience to the basic problem of overall decontamination effectiveness was to be found at Rocky Flats. This was because of the relatively much larger quantities of plutonium in process at Rocky Flats. No other facility had similar operating requirements. It was determined that, except for Rocky Flats, operating data for the overall performance evaluation of multi-stage HEPA filter systems that could be extrapolated for design uses was limited. Recorded operational data generally gave only what passed through the filters, not what was approaching them. There was likewise no evaluation of the relative effectiveness of each stage in a multi-stage system. Some information of this type was recorded at the Rocky Flats plant.

Data were obtained on plutonium loading on HEPA filters in two plenums at Rocky Flats. These were from Booster Plenum Number 3 in Building 771 and Booster Plenum Number 2 in Building 776 (1). These had historically experienced the highest loading rates in the plant. Booster Number 3 in Building 771 is used in a service very comparable to that anticipated for the new facility in terms of plutonium aerosol and chemical fume generation in process operations.

First stage filters removed from Booster Plenum Number 3 in normal service averaged 39 grams of plutonium per filter after a typical 90 days of service. Measurements were by a radiometric device called a drum counter with an estimated accuracy of plus or minus two grams. The specific activity of the plutonium (mostly oxide) used was 14.7 grams/Curie (g/Ci).

12th AEC AIR CLEANING CONFERENCE

The air flow through this plenum was a constant 1.1×10^6 cubic meters of air/day (28,000 cfm). This converted to an average loading rate of 0.8×10^{-6} micro-curies/milliliter ($\mu\text{Ci/ml}$).

It was also determined that the isotopic mix of material processed was such that if the concentration of Plutonium -239 oxide met the limits, other isotopes were well within allowable concentrations. Based on the above it was determined that the proposed exhaust systems must achieve a plutonium aerosol mass reduction ratio (entering : leaving) of greater than 10^7 . There was no established rule found for the application of filters to accomplish this.

Systems were found in operation which did accomplish a decontamination of 10^7 or greater. Table I presents data from one such system.

TABLE I

POINT	CONCENTRATION $\mu\text{Ci/ml}$	EFFICIENCY* $\eta \%$
Entering 1st Bank of Filters	0.8×10^{-6}	
Leaving 2nd Bank of Filters	8.0×10^{-12}	$\eta_{1-2}=99.999$
Leaving 3rd Bank of Filters	0.06×10^{-12}	$\eta_{3-4}=94$
Leaving 4th Bank of Filters	0.01×10^{-12}	$\eta_{4-5}=83$

A method of evaluating filter efficiencies quantitatively is presented in "The Mechanics of Aerosols" by N A Fuchs (2). In this work Fuchs writes "Apart from electrostatic forces, the four mechanisms active in the deposition of aerosols in fibrous filters are inertia, interception, sedimentation and diffusion". Fuchs further states, "All that can be said of the net efficiency by all mechanisms is that it is greater than each of the individual components but less than their arithmetical sum. It is clear that filter efficiency must tend to unity for very large and very small particle radii," and "-filter efficiency also tends to unity for very large and very small flow velocities.

*Calculated based on gram/day loadings. An air dilution factor of 8.1 applies between the 2nd and 3rd bank of filters.

With the fibrous media type filter theory and tests have indicated that total efficiency tends to unity for particles of smaller size than $0.03\text{ }\mu\text{m}$ (micro-meters) and larger than $0.5\text{ }\mu\text{m}$ (2) (3) (6). Testing and theory together indicate that there is a most penetrating particle in the $0.1 - 0.3\text{ }\mu\text{m}$ size range. This range appeared to be very important in plutonium work.

Fuchs shows the dependencies between the efficiencies of the various collection mechanisms and the parameters describing the gas flow, the aerosol, and the filter media. From these relationships, Fuchs has calculated, for a selected filter media and for two gas velocities, the filtration efficiencies ascribable to the different collection mechanisms. The size range of the aerosol particles assumed was $0.01\text{ }\mu\text{m}$ to $3\text{ }\mu\text{m}$.

Considerable research has been done on the characteristics of the plutonium aerosol. The most applicable works for this effort were found to be those by J Dymant (3), R A Kirchner (4), and K Stewart (5).

The plutonium aerosol size range from chemical processing operations has been found to be from less than $0.02\text{ }\mu\text{m}$ to several hundred μm , with a mass median diameter of between 1 and $2\text{ }\mu\text{m}$ from chemical processing operations, with as much as 20 percent less than $0.4\text{ }\mu\text{m}$.

From this data it was possible to characterize a particle "cloud" approaching the first filters. The total concentration used was $0.805 \times 10^{-6}\text{ }\mu\text{Ci/ml}$. The particles were treated as single, neutral particles, with electrostatic forces thus ignored. The particle cloud was subdivided into four specific clouds which were approximated to be monodispersed, with respective particle sizes of 0.03 , 0.10 , 0.30 , and $1.00\text{ }\mu\text{m}$. An associated weight fraction from the size distribution data was assigned to each specific cloud from actual data.

Fuchs' derived efficiencies were adjusted based on the HEPA filter media characteristics and media velocity of one centimeter per second. This was equivalent to 500 cfm through a $24 \times 24 \times 11\frac{1}{2}$ inch filter. Using these adjusted efficiencies and our derived particle clouds overall efficiency calculations were performed.

Three cases were then calculated

- Case I A combination of Fuchs' collection efficiencies and Dymment's size distribution.
- Case Ib Same as Case I, only using a more conservative efficiency in the 0.1 μ m (most penetrating size range 93% vs 96%).
- Case II Combination of Fuch's collection efficiencies and Kirchner's size distribution.

The results from these analyses are plotted on Figure I for comparison. They showed what was felt to be remarkable correlation, with the calculated results being conservative relative to the measured, as was anticipated and has been demonstrated (6).

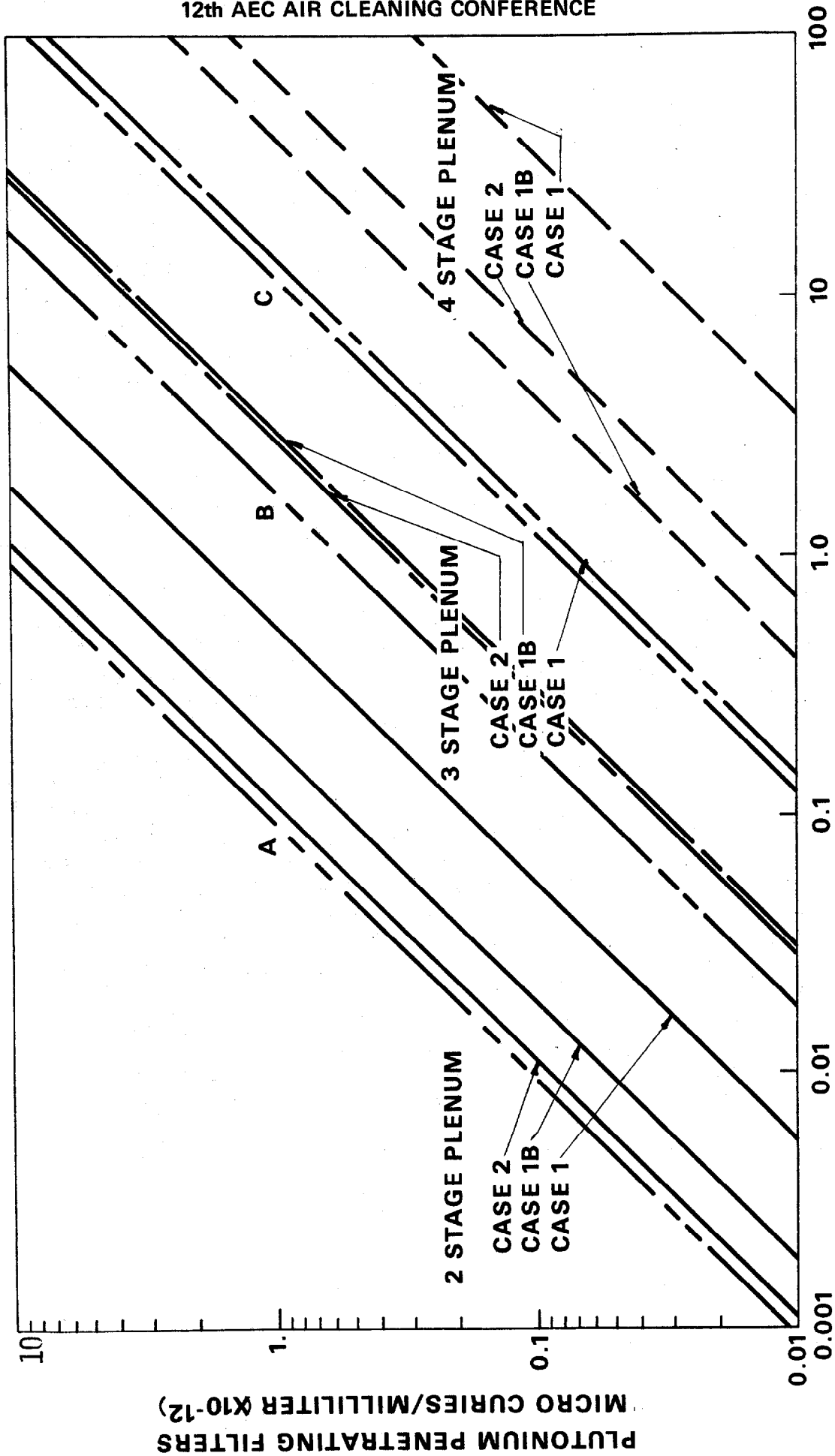
The aerosol collection process in a deep bed filter is identical to a fibrous filter media, ie, a collection by several different process mechanisms. No work has been found, however, that on a theoretical basis applies the theories of aerosol collection to a packed bed filter. Previous experience with deep bed sand and fiberglass filters is extensively reported⁽⁷⁾.

Using the penetration rates for sand beds found by C L Cheever, et al, (8) calculations showed that a deep-bed sand filter in series with two HEPA filters would provide the necessary decontamination. A 30-inch deep sand bed was required. This bed was found to be roughly equivalent to a single HEPA filter for the particle sizes remaining airborne after two stages of HEPA filters. No credit was taken for the approximately five feet of gravel and coarse sand required to build a deep-bed filter. Data indicated that fiberglass deep bed efficiency was equivalent to that of sand.

Based on the results from the above analysis it appeared practical to apply calculation methods in the design of filtration systems providing the following conditions were met.

- 1 Potential load data were available.
- 2 Data were available to reasonably characterize the aerosol as to size distribution.
- 3 The filter media characteristics and performance were known to normally conform to the theoretical work, as was the case with the subject HEPA filters.

PLUTONIUM AEROSOL ATTENUATION
FOR SERIES STAGES OF HEPA FILTERS.



PLUTONIUM INPUT TO FIRST STAGE OF FILTERS.
MICRO CURIES/MILLILITER (X 10⁻⁶)

FIGURE 1

- 4 The analyst was aware of the possible influences which might result in degraded filter performance such as temperature, moisture, aging, chemical attack, and other causes of leakage, and were to make appropriate safety allowances.

Using the calculated results it was determined that the systems would require a minimum of four series HEPA filters, each stage testable, or a combination of a minimum of two HEPA filters in series with a deep-bed filter.

Safety

The essential aspect of assuring the performance of any filtering system was found to be the clean-up and safety features provided ahead of the final filters. A model system was developed which included the operating safety features resulting from the safety evaluation. This model is shown in Figure II.

Normal Operation

Both HEPA and sand filter systems have failed in normal operation in some degree, generally due to chemical attack. The model developed includes scrubbers and other provisions as necessary to reduce such a possibility to the lowest practicable level. This risk was therefore evaluated as safely provided against in the model system based on actual operating experience.

The filtering system must function reliably through any credible accident. No maintenance shutdown of systems is allowable. Air flow control is the primary means of confinement of the radioactive materials within the building during normal operation. Exhaust system filters are a final containment barrier between these materials and the outside.

Redundancy of filters, plenums, fans and other essential components is widely accepted practice and has been proven reliable (9). A minimum of two parallel, full-duty rated fans were selected for reliability purposes. Two approaches were considered for the redundancy in the HEPA filter systems. 1) a spare plenum, shared by several plenums where practicable, and 2) oversized individual systems with valved cross-connections to other units. The latter approach was selected because of normally longer service life and less severe normal duty on the filters. Emergency transfer is to an already operating system rather than to a system which must first be started.

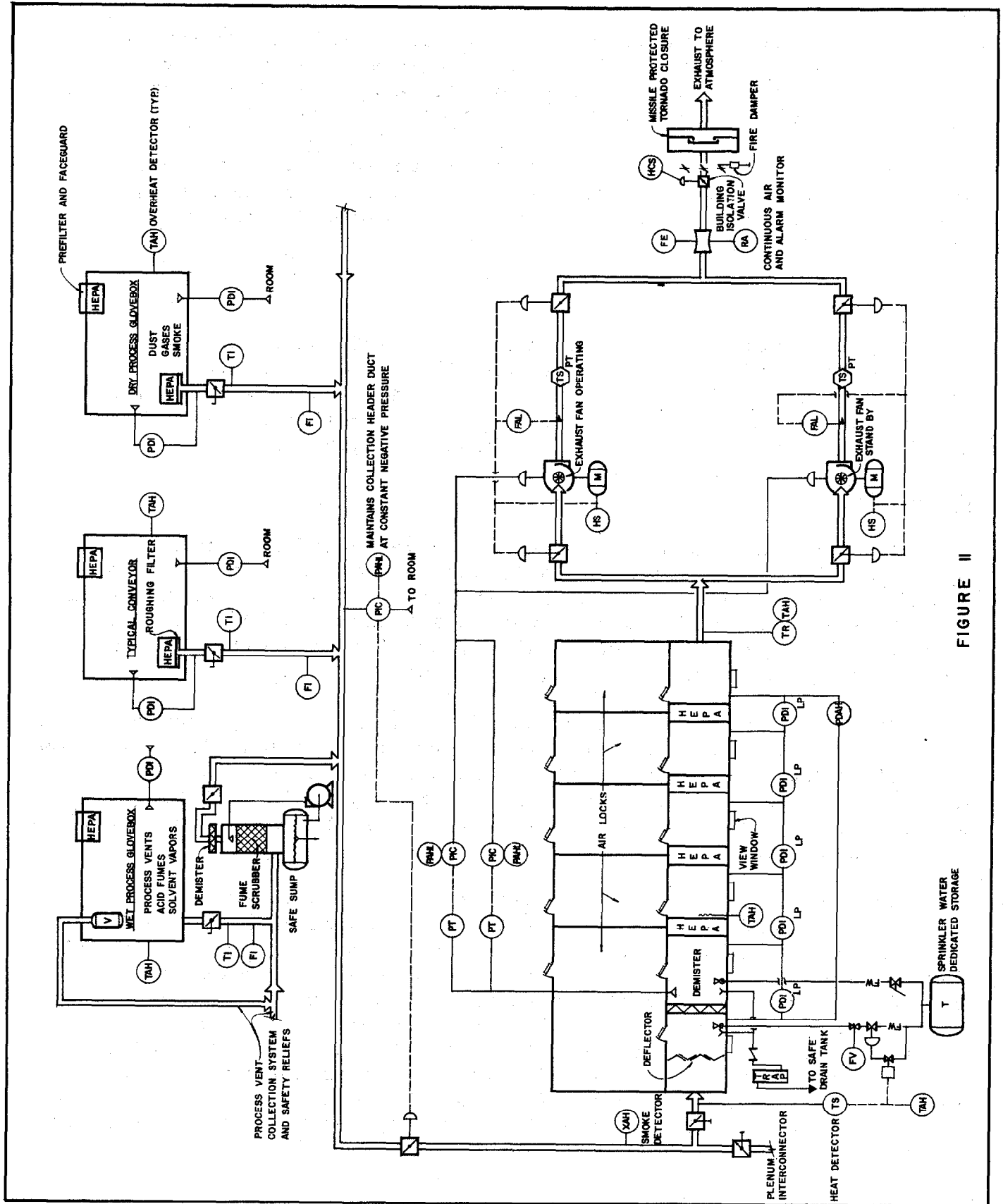


FIGURE II

A failure mode and effects analysis was determined to be an essential step in final systems design to assure that the failure of no single system component (including control elements) could disable a system.

Fire and Smoke

The possibility of fires, both duct propagated and internally generated, was accounted for, and a study was conducted to identify the filter exposure and methods of filter fire protection. Sand filters are fire resistant. As considered for the facility at Rocky Flats, a sand filter would be located down-stream of and in series with a HEPA filter bank. The emphasis was therefore placed on the exposure of HEPA filters to hot gases, burning debris, and sparks.

To provide adequate HEPA filter fire protection, a number of safety aspects in the design of the ventilation systems were considered. This analysis was based on several works (9), (10), (11), (12), (13), (14).

In a facility of all steel or concrete construction, the combustible material is made up of the dust generated in the operating or maintenance areas, the volatile gases released in production areas, flammable liquids used in the production and/or maintenance procedures, and any trash or debris left unnoticed in the facility.

The fire-resistant filters in the ventilation system collect the combustible fuel as dust, lint, or chemicals. The probable ignition source is from outside the system housing, in the form of sparks and flaming debris carried into the exhaust system. These incandescent particles from the primary fire can start secondary fires in a contaminated exhaust duct system, or start a filter fire. Due to the pyrophoric nature of some plutonium forms (metal sub-oxides, hydrides, etc), these fires can also be started by heat transmission from fires in surrounding areas or adjacent equipment, from welding and burning operations carried out in the vicinity, and from static discharges within the duct system or filter housing. The direct exposure of unprotected HEPA filters to hot gases, fires, smoke, and moisture can degrade the integrity of the system, and in severe cases cause a loss of containment.

The smoke generated within a building in the event of a fire should also be vented through the building air filtration system to assure sufficient visibility in the facility so that fire fighting personnel can effectively fight the fire.

Domning's work (13), (14), indicated that the metal mesh screen type of mist eliminator effectively removed smoke particles from the air stream and prevented clogging of the HEPA filters.

The HEPA filter systems proposed for the New Plutonium Recovery Facility at Rocky Flats, incorporated essential design features for filter fire protection. These include the following as described in references (9) through (14).

- 1 Fire-resistant pre-filters at the glovebox and room exhaust ports.
- 2 Mist eliminators and scrubbers where vapors or fume are involved.
- 3 Long duct runs (over 20 feet) to the final filter plenums.
- 4 A cooling chamber, smoke and heat actuated, water spray type, with a metal mesh screen combination mist eliminator and spark arrester, ahead of the final filters.
- 5 Manually operated fire sprinklers for fire suppression on the first stage of the multi-stage final filters.
- 6 An over-temperature alarm system in both the gloveboxes and the exhaust ducts.

Explosion

The risk due to an explosion was evaluated in detail. The type of explosion which could occur in a glovebox was considered to be the deflagration type. Much work has been in this area and is reported (15).

Considerable work has been recently done at Rocky Flats on the possibility of an explosive gas mixture reaching a plenum in the event of a glovebox fire. This danger does occur where large quantities of plastic windows may be involved. This can be overcome by using safety glass or plastic coated glass windows.

Earthquake

The effect of a postulated earthquake on HEPA filter installations can be analyzed. HEPA filter plenums are steel structures and can be designed sufficiently rigid to withstand earthquake forces without detrimental effect.

A sand filter containment structure can be designed to withstand fairly large earthquake forces. However there is not data available on what happens to the filtering efficiency of a sand bed when subject to shock or vibratory forces. By the nature of the bed it is assumed that the earthquake will not seriously degrade the effectiveness of a sand filter.

Tornado

Filter systems must be protected against tornado forces (minus 3 psig) on exhaust outlets. Study considerations were 1) the ability of the systems to inherently withstand the flow velocities and pressures, 2) use of relief devices in the ductwork, and 3) use of pressure-actuated closures. A rough analysis was performed of the dynamic forces generated within a system when tornadic pressures were seen at the exit. These showed that HEPA filters would see differential pressures well in excess of their rated maximum. Relief venting probably protect the filters but the system could not be tested without a very costly and complicated arrangement of components. A pressure activated closure gave the best protection available, considering reliability and availability. Such a closure valve, manufactured by LUWA Ltd, has been evaluated for this purpose at Oak Ridge and is reported (17).

Other

Consideration was given to such events as misoperation of equipment, inadvertent sprinkler release, improper maintenance, and operational failure of essential components. Design solutions and/or operating procedures were found for all cases considered.

Fixed sprinkler water supply quantities for filter protection were provided stored in earthquake resistant tanks within the containment structure. A looped sprinkler water supply system was provided with a minimum of two feed lines to each filter plenum. Raschig-ring filled drainage tanks were provided for the collection of the sprinkler water. These were necessary for nuclear safety.

Centrally supervised alarm monitoring and recording of all system performance parameters and maintenance requirements was found essential. Differential pressure, overtemperature, and smoke alarms were provided throughout the system. CAMs (Continuous Air Monitors) were provided at the outlet from each filter plenum. CAAMs (Continuous Air and Alarm Monitors) were provided in each exhaust duct from the building.

A basic principle of exhaust air-cleaning systems is that no credit can be taken for safety if the HEPA filters are not regularly tested. Regular in-place testing of both on-line and standby systems is necessary because of deterioration that can take place even when the systems are not being operated.

Most in-place tests are basically leak tests. The leak test is the most practical means of testing installed HEPA filters in multiple filter systems. Using filters of known efficiency, as certified by an AEC Filter Test Station, it is only necessary to be sure that no subsequent damage has created a hole in the filter, and that each filter is installed leak-tight in the system. A leak test will prove this.

Cost Comparison

For the cost estimate, a system of four final HEPA plenums containing four stages of filters was compared to a system of four two-stage HEPA filter plenums followed by a deep bed sand filter. The requirement for four separate HEPA filter plenums was determined from the building arrangement applicable at the time of the study.

The total system models were not estimated, only that work sufficient to evaluate cost differences. It was decided that the fire protection system for HEPA filters, developed at Rocky Flats subsequent to the 1969 fire, would be provided for the primary HEPA filters in either case.

The estimate shows that the installed cost of the HEPA filter system is approximately 1/2 of the cost of the HEPA plus sand filter system.

Recommendations

It is recommended that the following be considered for plutonium processing facilities glovebox and cell exhaust filtering systems.

1 Multiple filter plenums containing multiple testable stages of HEPA filters.

2 A sprinklered cool down chamber with a demister and spark arrester screen should precede the first stage of the HEPA filters. This cooling spray should be automatically actuated by an air temperature or smoke sensor in the approach ductwork. A manually actuated sprinkler system should be provided to cover the face of the first stage filters. A heat detection system should also be provided immediately downstream of these filters.

3 The approach ductwork to each plenum should be cross-connected with the nearest alternate plenum by remotely actuated isolation valves. Two fans are required with each plenum, each rated for the normal capacity of the plenum. The two fans together must be rated for the sum total capacity of the cross-connected systems.

4 A vessel vent collection system with its demisters, reflux-type condensers, and scrubbers should be used for the wet chemical processing systems.

5 Dry process gloveboxes should have HEPA prefilters at the exhaust connection.

General Conclusions

This study has been productive toward establishing an effective filter plenum design criteria for a facility of the nature of the proposed New Plutonium Recovery Facility at Rocky Flats. Filter plenums to provide the necessary decontamination of the exhaust gases on a safe, reliable, and continuous basis can be developed. Adequate fire protection, and protection from the destructive effects of earthquakes and tornados is feasible.

It is also evident that more testing needs to be done to determine the effectiveness of multi-stage HEPA filter systems in actual use. More complete data will be invaluable for new design work. Additional operating data should be taken at Rocky Flats, Building 771, on Booster Number 3 and other plenums subject to similar loading conditions throughout the AEC facilities. There is presently a lack of the type of direct operating data that can be extrapolated for design purposes.

BIBLIOGRAPHY

- 1 Letter Communication, L F Grill, Dow Chemical USA to L D Leeper, C F Braun & Co, November 15, 1971.
- 2 Fuchs, N A "The Mechanics of Aerosols". The MacMillan Company, New York, 1964
- 3 Dymont, J "The Penetration of, Fibrous Media by Aerosols as a Function of Particle Size". CONF-337-351, August 1963
- 4 Kirchner, R A "A Plutonium Particle Size Study in Production Areas at Rocky Flats". American Industrial Hygiene Association Journal, Vol 27 July-August 1966
- 5 Stewart, K "The Particulate Material Formed by the Oxidation of Plutonium". Progress in Nuclear Energy, Technology, Engineering, and Safety, Series IV, Vol 5, The MacMillan Company, New York, 1965
- 6 Stafford, R G and Ettinger, H J "Filter Efficiency vs Particle Size and Velocity". LA-4650, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, 1971
- 7 Juvinall, R A, Kessie, R W, and Steindler, M J "Sand-Bed Filtration of Aerosols: A Review of Published Information on Their Use in Industrial and Atomic Energy Facilities". ANL-7683, Argonne National Laboratory, Argonne, Illinois, June 1970
- 8 Cheever, C L, McFee, D R, Secllet, J, and Duffy, T L, "ZPPR Roof Sand Filtration of Uranium, Plutonium, and Uranine Aerosols". CONF-660904, Proceedings of the Ninth AEC Air Cleaning Conference, 1966
- 9 Burchsted, C A, and Fuller, A B, "Design, Construction, and Testing of High Efficiency Air Filtration Systems for Nuclear Application". ORNL-NSIC-65, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1970
- 10 *Order* Smith, S E, Hall, F J, Holmes, W E, and George, A F, "Protection Against Fire Hazards in the Design of Filtered Ventilation Systems of Radioactive and Toxic Process Buildings", AWRE O-24/65, Atomic Weapons Research Establishment, Aldermaston, Berkshire, July, 1965

BIBLIOGRAPHY

- 11 Dymant, J, "Present Status of the Design and Testing of Radioactive Filtration Installations and Associated Aerosol Research", CONF-700816, Proceedings of the Eleventh AEC Air Cleaning Conference, 1970
- 12 Domning, W E, "New Fire Protection Systems for Filter Plenums", CONF-700816, Proceedings of the Eleventh AEC Air Cleaning Conference, 1970
- 13 Domning, W E, "Design of Filter Plenum Heat Exchangers", CONF-710401, Proceedings of the Rocky Flats Symposium on Safety in Plutonium Handling Facilities, April, 1971
- 14 Domning, W E, "Smoke and Heat Removal from Fires Occurring in Radiochemical Processing Buildings", ER Report March 20, 1972, Chemistry Research and Development, Dow Chemical USA, Rocky Flats Division, Colorado, 1972
- 15 Yao, C, de Ris, J, Bajpai, S N, and Buckley, J L, "Evaluation of Protection from Explosion Overpressure in AEC Gloveboxes", Factory Mutual Research Corporation, 1969
- 16 Letter Communication, Farrel, L C, Dow Chemical USA to Watt, J A AEC RFAO, June, 1972
- 17 Chester, C V, "Tests of the LUWA Blast Valve", ORNL-TM-2796, Oak Ridge National Laboratory, Oak Ridge, Tennessee, December 1969

DISCUSSION

NEWMAN: This is not a question so much as a comment. Dr. Isbin touched on this this morning. Reference was made that the limits set forth in Chapter 0524, which I think are similar to those in Part 20, were a definition of "as low as practicable." I'm not sure what the Commission's guidelines are for their own plants, but I can vouch for the fact that as far as the commercial, or the utilities, are concerned, "as low as practicable" for normal operation is as much as a number of orders of magnitude below the Part 20 limits. Proposed Appendix I will support this. So I think the record should be clear that we are not designing things only to concentrations defined in Part 20, but, indeed, much lower.

KEIGHER: Two questions in relation to automatic sprinkler systems. Why is there manually operated sprinkler protection on the first HEPA bank filter? Is it correct that there is no fire suppression system on the remaining HEPA banks?

HETLAND: The manually-operated valve is there in case we have an over-temperature on the first stage of the HEPA after automatic actuation. It is more or less an emergency procedure. The remaining HEPA banks have no fire protection.

KEIGHER: You mean the manual system is supplemental?

HETLAND: Right.

FULLER: I'm of the opinion that the LUWA blast valve is uni-directional. Therefore, two would be required for a blast effect of ± 3 psi. Is this your understanding?

HETLAND: No. A tornado is defined as a pressure excursion of -3 psi on the outside, so we would protect the building from being vented during those conditions.

ETTINGER: Where you show the efficiency for the fourth bank of filters to be 83%, which is extremely low, is this likely to be leakage around the filter rather than penetration through the filter and to be unrelated to the performance of the filter, itself?

HETLAND: Right. As mentioned, these are field data on a system that has been in service up to 15 or more years. This is probably leakage but we don't know for sure.

EFFECTS OF HIGH-LEVEL GAMMA RADIATION EXPOSURE OF HEPA FILTERS*

C. L. Cheever, C. H. Youngquist, P. R. Hirsch,
J. C. Hoh, D. S. Janetka, and H. R. Fish
Argonne National Laboratory
Argonne, Illinois

Abstract

Evaluation of the effects of stepwise exposure of five 12 x 12 x 6 inch HEPA filters to cobalt-60 gamma radiation are reported. Two of the filters had glass-pack seals and cadmium plated steel frames, two had glass-pack seals and chromized steel frames, and one had a pressed wood frame. An additional pressed wood frame filter was tested as a non-irradiated control. The filters were irradiated to nominal exposures of 10^7 , 10^8 , 5×10^8 , 10^9 , and 1.5×10^9 R. At the start and after each period of irradiation, the filters were tested at rated flow to determine the percent penetration of compressed air generated DOP aerosol. The filters were then stressed at two to three times rated flow and the penetration tests were repeated at rated flow. Two of the steel frame filters were irradiated in an argon atmosphere and the other filters were irradiated in air. All tests showed acceptable ($< 0.03\%$) penetration results. There was no significant change in penetration except as measured in the last step for filter number four.

Flat sponge neoprene and PVC gaskets were also irradiated in both argon and air as above. The effects were measured by observation, leak rate measurements, and Shore durometer hardness tests. The neoprene gaskets are preferred, although they became hard. The PVC gaskets became tacky and were unacceptable.

The HEPA filters continued to perform acceptably after irradiation to $> 10^9$ R of cobalt-60 gamma radiation.

Introduction

Tests have been conducted at Argonne National Laboratory (ANL) to evaluate effects on and performance of high efficiency particulate air (HEPA) filters subjected to high dosages of gamma radiation. The tests were carried out to provide engineering guidelines for the installation of HEPA filters inside the argon atmosphere main cell of the new ANL Hot Fuel Examination Facility (HFEF)^(1,2). There is an advantage in having the first HEPA filters in series installed inside the cell in this type of facility. This retains most of the radioactive particulates within the shielded cell and remote handling equipment is available for removal of contaminated filters. The estimated maximum exposure to any of the in-cell HEPA filters due to gamma radiation from irradiated reactor fuel elements was 4×10^8 roentgens (R) per year. Accordingly, tests were designed to measure changes in penetration of compressed air generated dioctyl phthalate (DOP) aerosol⁽³⁾, visible effects, and changes in gasket hardness due to stepwise cobalt-60⁽⁴⁾ gamma irradiation of HEPA filters to 10^7 , 10^8 , 5×10^8 , 10^9 , and 1.5×10^9 R. The gamma irradiation doses were designated for the filter face nearest the cobalt-60 source. The filter face away from the source would receive about 70% of this exposure due to distance and somewhat less than this due to

*This work was performed under the auspices of the U. S. Atomic Energy Commission.

12th AEC AIR CLEANING CONFERENCE

attenuation by the filter materials. The radiation dose rate was 5×10^5 R per hour at the front faces of the filters. Total irradiation times were 20; 200; 1,000; 2,000; and 3,000 hours to obtain the above dosage steps. Irradiation dosimetry was by measuring the change in transmittance of cobalt glass and this technique had been compared to ferrous sulphate dosimetry measurements. The radiation dose measurements are considered to be within $\pm 5\%$ accuracy.

The size 12 x 12 x 5-7/8" HEPA filters used in these evaluations were manufactured by Flanders Filters, Inc., and were constructed as indicated in Table I.

Table I
Test HEPA Filters

<u>Filter Number</u>	<u>Frame Construction</u>	<u>Filter Media</u>	<u>Separators</u>	<u>Sealant</u>
1	Cadmium plated steel	Waterproof glass fibers	Asbestos	Glass fiber pack
2	Cadmium plated steel	Waterproof glass fibers	Asbestos	Glass fiber pack
3	Chromized steel	Waterproof glass fibers	Asbestos	Glass fiber pack
4	Chromized steel	Waterproof glass fibers	Asbestos	Glass fiber pack
5	Fire retardant particle board	Waterproof glass fibers	Asbestos	Polyurethane foam
6	Fire retardant particle board	Waterproof glass fibers	Asbestos	Polyurethane foam

The above filter media meets the MIL F 51079A standard. Organic starch binder is not to exceed 5% by weight, of the glass fiber media. Metal frame, glass fiber pack filters were selected for the tests because it was thought they would be quite resistant to radiation damage. The particle board frame, polyurethane foam sealant filters were tested to provide comparative information. Filter number six was not irradiated but was tested along with the irradiated filters as a control.

Filters were irradiated with aluminum sheet metal plates attached to their faces for internal purging at a rate of 5 cc per minute with argon or air as indicated. Also, gaskets were placed between sheet metal aluminum plates and the void space was purged as above during irradiation. This was done to provide an argon atmosphere for the filter media and also for one surface of the gasket material and to provide similar conditions with an air atmosphere.

Filter Tests

Measurement of DOP aerosol penetration through the test filters was carried out with the equipment shown in Figure 1.

The ANL fabricated single Laskin nozzle generator shown in Figure 1 was used to produce DOP aerosol of about 0.8 microns light scatter mean diameter. The TDA-2C linear Aerosol Photometer with a 0.01% scale as shown in Figure 1 was used to measure the test aerosol concentration upstream and downstream from the filter. The penetration was taken as the average of 2 to 4 penetration test readings. Initially and after each irradiation step, filters were tested at rated flow of 135 cfm, then stressed for 15 minutes to 1 hour at 2 to 3 times rated flow and then retested for DOP penetration. The stressing at increased flow rate was done to simulate the increase in pressure differential across the filter media as dust loading increases with usage. Since the air flow tests were of short duration, effects that might be apparent only after prolonged service would not be detected. No significant changes were found in any of the DOP penetration tests subsequent to stressing. DOP penetration test results are listed in Table II.

Table II

% DOP Penetration

Gamma Exposure, R:	0	10^7	10^8	5×10^8	10^9	1.5×10^9	Irrad. Atmos.
Filter No.							
1	0.0007	0.0012	0.0015	0.0021	0.0016	0.0017	Air
2	0.0012	0.0020	0.0020	0.0027	0.0020	0.0017	Argon
3	0.0018	0.0021	0.0024	0.0025	0.0021	0.0024	Air
4	0.0019	0.0017	0.0021	0.0023	0.0019	0.0120	Argon
5	0.0035	0.0046	0.0052	0.0052	0.0053	0.0058	Air
6*	0.0016	0.0022	0.0019	0.0020	0.0021	0.0022	Control

* No radiation exposure, control.

The face of filters number 1, 3, 6, and 5 are shown in Figure 2 after irradiation to 1.5×10^9 R. Filter number 6, lower left, was the control showing no discoloration. Filter number 5, lower right, shows the polyurethane foam adhesive completely darkened and looking almost charred. The labels and particle board were also darkened. Filters number 1 and 3 at top showed some evidence of discoloration of separators and the white labels turned brown.

Gasket Tests

Closed cell neoprene and PVC gaskets were irradiated along with the HEPA filters and to the same nominal gamma radiation doses. The neoprene and PVC gaskets were nominal 3/4" wide by 1/4" deep flat gaskets. The neoprene gaskets had dovetailed corner joints while the PVC was continuously molded. The closed-cell black sponge neoprene gaskets were manufactured to ASTM D1056-SCE 43

12th AEC AIR CLEANING CONFERENCE

specifications. Prior to irradiation and after each irradiation step, the gaskets were placed between steel plates and loaded to 43 pounds per linear foot. This loading simulated the HFEF in-cell method of gasket compression by a 300 pound distributed weight on each of the 24 x 24 x 12" HEPA filters. The measured rate of in leakage was as shown in Table III.

Table III

12" x 12" Gasket Leakage at -2" H₂O, liters/min.

<u>Co-60 Gamma Irradiation, R</u>	<u>Neoprene</u>		<u>PVC</u>	
	<u>(Air Purge)</u>	<u>(Argon Purge)</u>	<u>(Air Purge)</u>	<u>(Argon Purge)</u>
0	0.025	0.075	0.26	0.338
10 ⁷	0.032	0.020	2.12*	0.426
10 ⁸	0.03	0.04	0.50	0.22

* Small groove noted across gasket, cause unknown.

The gaskets were tested for hardness by Durometer A-2 readings⁽⁵⁾ with results as shown in Table IV. The PVC gasket became tacky after exposure to 10⁸R and after exposure to 5 x 10⁸R it became unacceptably gooey.

Table IV

Durometer A-2 Hardness Tests
(average of 5 or more durometer readings)

<u>Co-60 Gamma Irradiation, R</u>	<u>Neoprene Gasket</u>	<u>PVC Gasket</u>
0	15.6	28.5
10 ⁸	26.5	28.8
5 x 10 ⁸	78.7	-

The neoprene gaskets hardened with exposure to gamma radiation as indicated. After irradiation to 10⁸R, a gray powder had formed between the gaskets and the aluminum plates for both the neoprene and PVC gaskets. Also, after 10⁸R irradiation, one portion of neoprene gasket was damaged due to sticking to the aluminum holder plate. This did not reoccur at the subsequent irradiation levels but indicates the potential problem of gasket adhesion to mounting surfaces.

Although the neoprene gaskets hardened, the seals may be acceptable if the seating remains undisturbed while weighted down.

Summary

Tests were carried out at ANL to determine the effect of high-level gamma radiation exposure^(6,7) to selected HEPA filters. Under test conditions, all filters showed acceptable (< 0.03%) DOP aerosol penetration over the entire exposure range of 10⁷ to 1.5 x 10⁹R. Metal frame, glass pack HEPA filters and

12th AEC AIR CLEANING CONFERENCE

neoprene gaskets have been selected for installation in the main cell of the ANL HFEF facility. Neoprene gaskets hardened but were preferred as the PVC gaskets became unacceptably gooey in these tests.

References

- (1) N. J. Swanson, D. P. Minesz, and J. R. White, "The Hot Fuel Examination Facility (HFEF)," Proceedings 19th Conference Remote Systems Technology, 3 (1971).
- (2) R. H. Swanstrom and P. R. Hirsch, "Argon Atmosphere Filter System in HFEF Hot Cell," Proceedings 18th Conference Remote Systems Technology, 159 (1970).
- (3) W. H. Echols and J. A. Young, Studies of Portable Air Operated Aerosol Generators, U. S. Naval Research Laboratory Report 5929, (1963).
- (4) U. S. Public Health Service, Radiological Health Handbook, U. S. Government Printing Office, (1970).
- (5) American Society for Testing Materials, Rubber: Carbon Black, Gaskets, ASTM Standards, Part 28 (1969).
- (6) American Society for Testing Materials, Symposium on Radiation Effects and Radiation Dosimetry, (1960), ASTM Special Technical Publication No. 286.
- (7) R. O. Bolt and J. C. Carroll, Radiation Effects on Organic Materials, Academic Press, (1963).

Figure 1
DOP Filter Test Apparatus

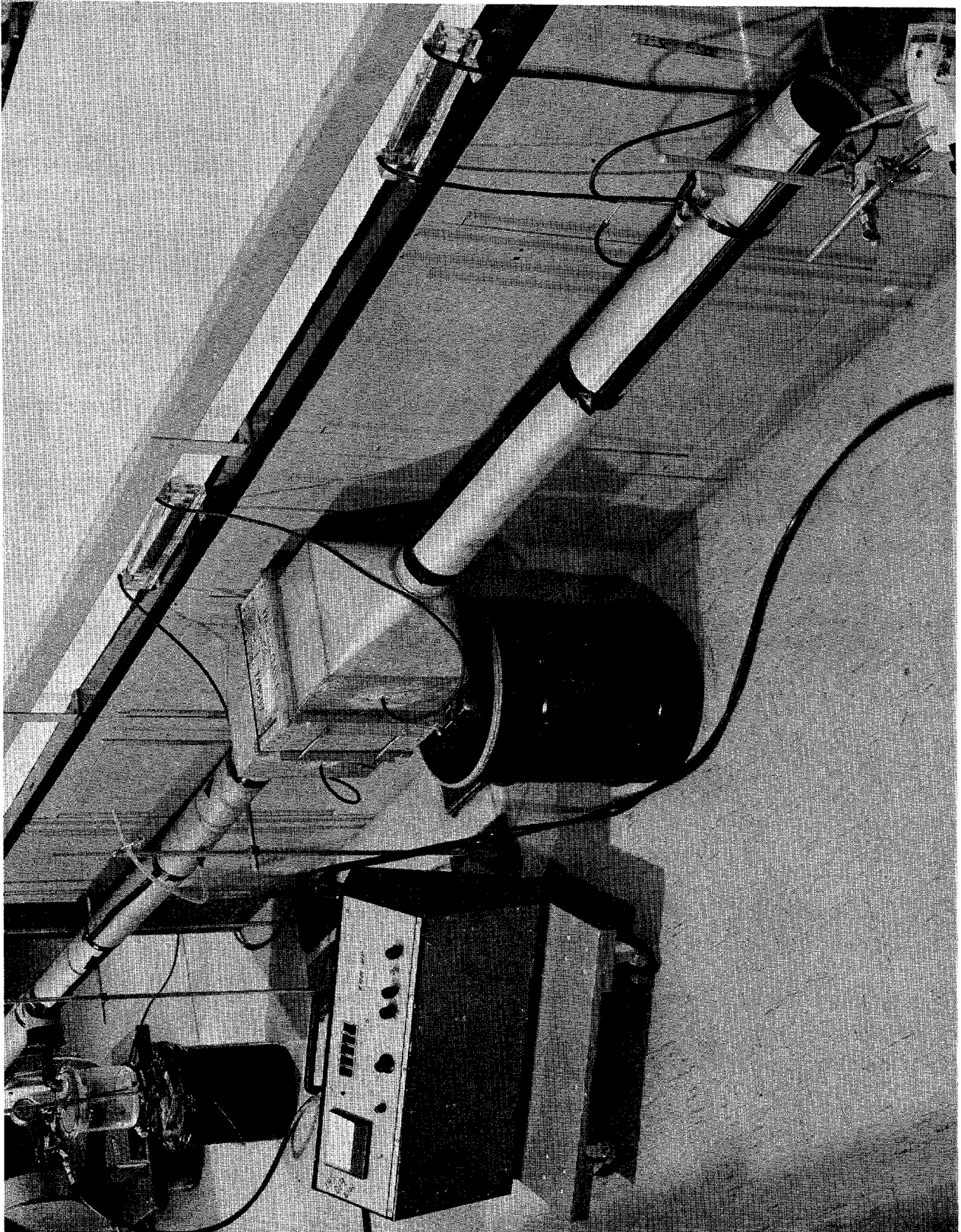
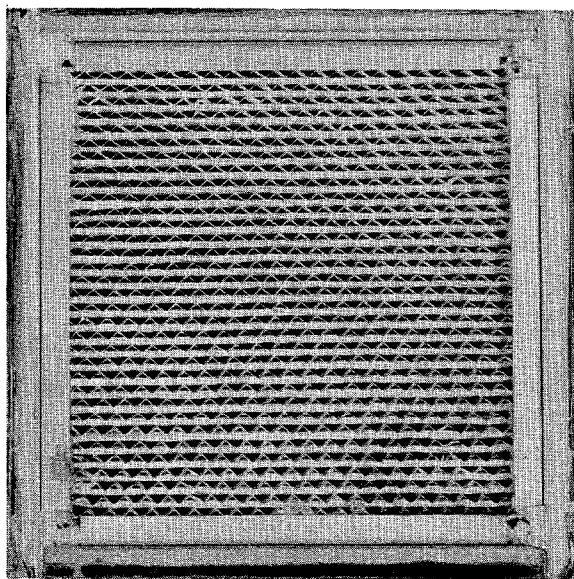
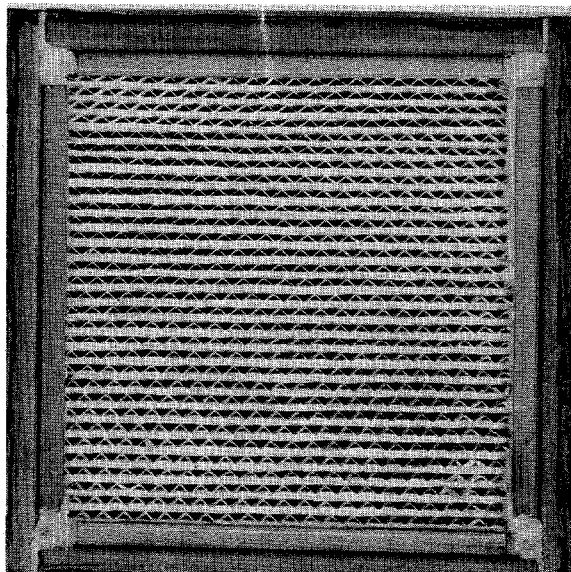


Figure 2

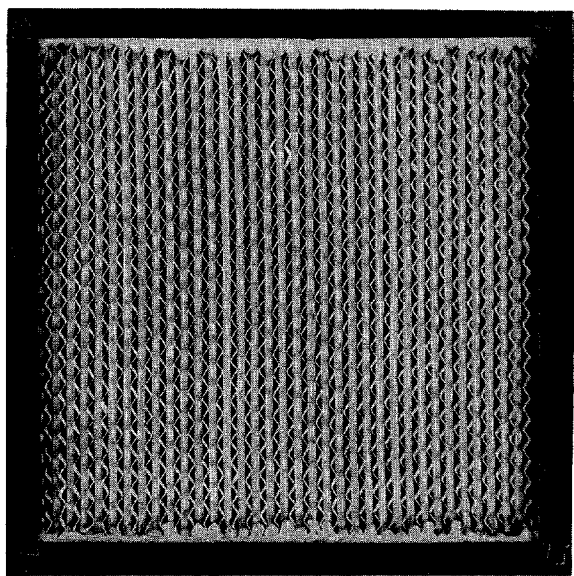
HEPA Filters After Cobalt-60 Irradiation to 1.5×10^9 R.



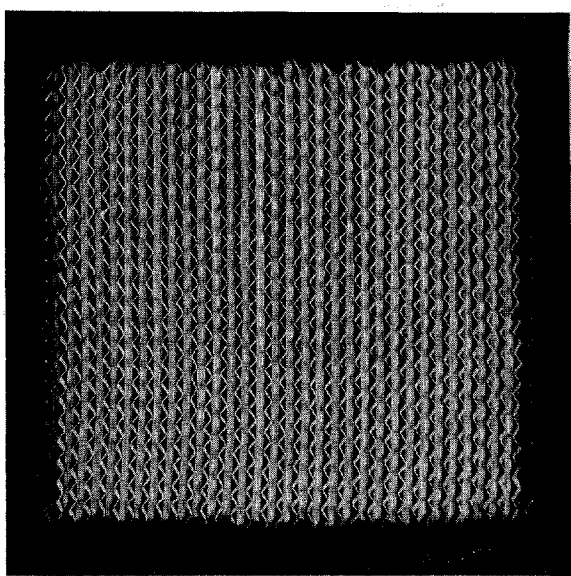
No. 1



No. 3



No. 6



No. 5

DISCUSSION

FIRST: Did you check your filters after radiation to find out how well they might withstand vibration, or other handling? I have the impression they become quite brittle and fragile.

CHEEVER: The filters were only subjected to the vibration of handling and transport to another building for DOP testing between irradiation steps and stressing at about 3 times rated flow for 15 minutes to one hour at each step.

MURROW: Did you notice any particular degradation of the pressboard frames?

CHEEVER: The pressboard frames darkened and may have been less strong; although we made no measurements. The filter frame didn't crumble.

JONES: Were these water-repellant filters or non-water-repellant?

CHEEVER: Water-repellant.

JONES: Will they be exposed to high humidity or dry air in service?

CHEEVER: Our application is in an argon atmosphere cell. This is very dry.

BURCHSTED: Did the hardened gaskets tend to crumble or tend to fall away from the filters?

CHEEVER: No. The gaskets remained intact except at one step. After a 10^8 R exposure, one piece of neoprene adhered and pulled off.